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Developing writing prompt assessments for the next generation science standards: Physical science

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DEVELOPING WRITING PROMPT ASSESSMENTS FOR THE NEXT GENERATION SCIENCE STANDARDS: PHYSICAL SCIENCE

A Creative Component

Submitted

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts in Science Education

Kristen Ann Birchard

University of Northern Iowa

May 2017

Abstract

The purpose of this project is to discuss the development of writing prompt assessments that are aligned with the High School Physical Science performance expectations of the Next Generation Science Standards. Eight writing prompts aligned with HS-PS1 Matter and Its Interactions were developed. These prompts utilize phenomena and real-life connections, while incorporating the three dimensions of the Science and Engineering Practices, Disciplinary Core Ideas, and Cross-Cutting Concepts. Along with the development of these prompts, key vocabulary words were identified, and rubrics were created to aide in the assessment of the students' responses. The quality of the writing prompts was also assessed using a tool modeled after the EQuIP rubric for lessons and units.

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am lucky to have him in my life.

I also want to thank my students. There are times when I get frustrated feeling like I work harder than them, but in the moments where I make a breakthrough with this student or that student it makes it all worthwhile. I love to watch them grow, and know that I was a part of that growth. This project is for them. I want my students to go forward, proud of the education they received at Eddyville-Blakesburg-Fremont Junior Senior High, knowing they are prepared for the challenges and experiences they will face. I truly believe that the Next Generation Science Standards, if implemented with fidelity, will better prepare them for these experiences, and this project was completed to help me to implement NGSS to the best of my ability. I also want to thank them, especially JG, for letting me "try out" some of my writing prompts on them, outside of the context of what they are currently learning, to identify parts that needed communicated more clearly, and to find grammar issues in the problems that I could fix before turning my project in.

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Chapter 1

Introduction and Framework

In the Fall of 2015 the state of Iowa officially adopted the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) and incorporated them into the Iowa Core (National Governors Association Center for Best Practices, Counc, 2010). Once considered the possible future of science education in the state of Iowa, they are now the current identity of science education in the state of Iowa. One of the added features of the NGSS/new Iowa Core, when compared to the old Iowa Core standards, is the addition of performance expectations. According to the National Science Teachers Association, performance expectations are not the “standards” teachers are typically accustomed to. The performance expectations found in the Next Generation Science Standards are statements of what teachers should assess for, or rather what students should know and **be able to do** upon the end of the course. The standards should never limit a curriculum, rather they identify what all students, not just some, must be able to demonstrate at a proficient level (National Science Teachers Association, 2014).

In my undergraduate science education preparation courses, there was talk about rigor and relevance, scientific inquiry, and depth of knowledge, but ultimately the standards we focused on (the National Science Education Standards) were about content. The new NGSS standards focus on learning in three dimensions and are clustered under specific performance expectations to encourage students to be able to show not just what they know, but how it is linked to the bigger picture. Students must be proficient in all components of NGSS. This includes the Science and Engineering Practices (SEPs), Cross-Cutting Concepts (CCCs), and the Disciplinary Core Ideas (DCIs) and they must be able to demonstrate this understanding in non-rote manners through the performance expectations.

When preparing the performance expectations (PEs), a committee was formed to guide the development of assessments for the Next Generation Science Standards. This committee, named the Committee on the Assessment of K-12 Science Proficiency, has members from numerous universities across the United States, Loveland High School in Colorado, and several federal organizations. What they found and identified as one of the assessment "challenges" for these PEs is that students will need multiple, and varied, assessment opportunities (National Research Council of the National Academies, 2014). This committee was charged specifically with addressing the preparation of end-of-course summative assessments that a school could use to demonstrate student proficiency such as a state exam, rather than classroom assessments, both formative or summative that drive teacher decision making processes. Despite the difference in focus of the assessments, the same issue is present for classroom teachers. Right now there are little to no assessments developed to match the performance expectations set forth by the Next Generation Science Standards. There are no resources to pull from, therefore teachers need to prepare and provide their own forms of assessment to be able to identify what students know, understand and are able to do with these new standards, all on their own.

Performance expectations typically have three parts. Each one informs teachers of the science and engineering practice students should be able to do, the disciplinary core idea students should know and understand, and the cross-cutting concept that links this understanding to their previous understanding. While some performance expectations ask students to design and carry out an experiment ("Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles" -- HS-PS1-3) many of the PEs can be addressed in writing. Performance expectations calling for actions like analyzing and interpreting data, ("Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration" -- HS-PS2-1) or engaging in argument from evidence ("Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs" -- HS-PS1-5). are standards that fall into this category. This paper will specifically address some of the performance expectations that can be assessed through student writing in response to questions posed to students. This creative component is focused specifically on this category of PE and will be completed to prepare examples of assessment probes high school teachers could use. These probes can be used to begin to assess how well their students demonstrate proficiency in the targeted PEs that fall into this category and will be measured via writing prompts.

There are eight SEPs in the NGSS, listed below (Achieve, Inc., 2013). The performance expectations marked with an * are ones for which writing prompts may not be appropriate. However, writing prompts are a viable option for the remaining SEPs.

1. Asking questions (for science) and defining problems (for engineering).
2. Developing and using models.
3. Planning and carrying out investigations. *
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information.

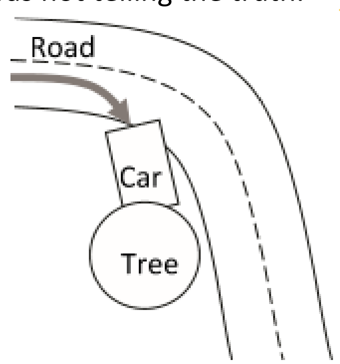
Why writing prompts? In 2013, while working on a Science Network project through the Great Prairie Area Education Agency (GPAEA), I came across a series of writing prompts developed out of Montgomery County Schools in Maryland. At the time, I was working with a group of teachers on developing instruction and assessments for a particular disciplinary core idea on motion. This standard (HS-PS2-1) involved analyzing data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. This work took place prior to the adoption of the Next Generation Science Standards in Iowa. In my searches for what other teachers were doing on this topic, I discovered that this school had developed a few different writing prompts that aligned with this performance expectation (as well as Newton's other laws of motion) as a part of a project the teachers of their Integrated and Applied Physical Science classes had been involved in. Some of these prompts are included in Appendix A (Car Accident) and Appendix B (Sledding) (Schools, 2012).

These resources were written to align with their school district's standards at the time, but their current website indicates they have since adopted NGSS voluntarily (in Maryland) and these resources are still available on their website as tools teachers can use in their units. They were a source of inspiration for me at the time, providing the idea for this project. I test drove this idea, using the two prompts identified in Appendices A and B in my Physical Science classes. (At my school, Eddyville-Blakesburg-Fremont Junior Senior High, the NGSS are taught there a three-course curriculum. I teach a 9th grade Physical Science course, and my colleague teaches 10th grade Biology and 11th grade Environmental Science courses. My other courses are science electives including Chemistry, Physics, and Advanced Chemistry.) The results were not spectacular, mostly because my students struggled with putting thoughts onto paper, but the process gave me a deeper understanding of what students knew compared to my typical approach of just asking them recall-type questions about the content.

Writing prompts can be an effective assessment strategy for a lot of reasons that will be described more thoroughly in Chapter 2. One such reason is that they show individual understanding. My experiences with Physical Science students over the last eleven years is that they lack a lot of confidence in themselves, unnecessarily, and often use each other as a crutch to justify or support their understanding. When I ask students to write answers to these writing prompts, they cannot rely on another student. For this reason, what they write better depicts their individual “filing cabinets” in their brains. I am able to quickly identify those students who are making connections, those who have only a superficial understanding, and those who are struggling with the content. My school uses a Multi-Tiered Systems of Support (MTSS) approach and we are in the beginning stages of using Professional Learning Communities (PLC) to improve student learning. Identifying those students who are making connections, those who have only a superficial understanding, and those who are struggling with the content is important in deciding how to implement interventions with students, and with which students, to ensure all students are learning at high levels. This is one of the aims of MTSS, a local initiative where we expect that 80% of our students should be proficient given the original instruction, while other students might need mild interventions to be proficient and even fewer students need more substantial interventions. Identifying students’ levels of understanding is critical for this process of intervention to take place.

Some students struggle with written language, and I can easily modify these written assessments to generate an oral conversation with those students in an individual setting. For the remainder of my students, when I initially put writing prompts into my assessment rotation, many of my students had difficulty expressing their understanding in this type of format, not just those with writing goals. They much preferred assessments where they were given multiple choice type questions (but were sorely disappointed to discover I very rarely use that type of assessment) over those where they have to write a short-answer type of response. Prior to implementing these prompts from Montgomery County, students were accustomed to questions like, "Define Newton's First Law of Motion and give an example of how you see it in your daily life." With the first prompt, "Car Accident" they were instead given the following:

A police officer is called to the scene of a car accident. In his accident report he sketches the scene and describes it. According to his description the car went off of the road and hit a tree right after a bend. The driver claimed that a second car ran them off the road by hitting them from behind. Using his observations and his knowledge of physics, the police officer determined that the driver was not telling the truth.



Explain how the police officer determined that the car was not run off the road by a second car that came from behind. In your response, be sure to include:

- labels of the forces that would have acted on the car if it were hit from behind.
- labels of the forces that must have acted on the car to have in follow the path indicated with the arrow on the sketch of the scene.
- how forces affected the motion of the car.

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Figure 1: Montgomery County Schools Sample Writing Prompt: Car Accident

A simple, one or two sentence response does not cut it here. As I have become better trained in the Next Generation Science Standards and have begun to focus more on 3-

dimensional units (ones that address the SEP(s), CCC(s) and DCI(s) linked to each PE), these types of assessments have become more logical to my students. Students have begun to see how all of the pieces fit and are better able to express themselves in writing. Student assessment needs to match student instruction. If students are being asked to focus three-dimensionally during instruction, their assessment should too. Writing prompts are one avenue that make this possible.

The goal of this creative project is two-fold. The first goal is to create writing prompts focusing on the Performance Expectations tied to the first Physical Science Disciplinary Core Idea (DCIs) described in the NGSS/Iowa Core Science Standards (HS-PS1). These performance expectations focus on topics related to “Matter and Its Interactions” (HS-PS1) including “Structure and Properties of Matter” (PS1A), “Chemical Reactions” (PS1B), and “Nuclear Processes” (PS1C). “Forces and Motion” (PS2A), and “Types of Interactions” (PS2B). These writing prompts will be written so students can assess three-dimensional learning. Each writing prompt will incorporate Science and Engineering Practices (SEPs), Disciplinary Core Ideas (DCIs) and Crosscutting Concepts (CCCs) that are identified as appropriate to each PE. They will also be aligned with the evidence statements that are connected with each Performance Expectation (NGSS Lead States, 2013). During future revisions of this project, the remaining high school Physical Science performance expectations will be the inspiration of additional writing prompts. (For the near future, these writing prompts will be developed for my Physical Science class only, because my other classes are elective classes that do not require implementation of the NGSS. However, prompts could be developed further down the road for those courses as well.)

The second goal of this creative component is to develop rubrics for each writing prompt that will help objectively assess student proficiency. When grading the writing prompts I used from Montgomery County Schools (Appendix A and B), I had a hard time deciding what grade I thought each response deserved. This challenge is the driving factor of this second component for this creative project. High quality rubrics are needed to decrease the subjectivity in evaluating students' work.

With these two goals achieved, this project will help to provide insights for me and any of my peers that might come across this project as we go through the process of implementing the NGSS into our curriculum. Given my work through the GPAEA, it is a natural extension, having already discussed ways to incorporate the NGSS into my lessons, to begin to take a look at how to incorporate the standards into my assessments as well.

Chapter 2

Relevance and Literature Review

Next Generation Science Standards

In recent years, our nation's science education system has been subject to criticism. No longer is the United States at the top of the scales, being among the first countries to make major scientific and technological advances including sending a man to the moon. The United States has lost its economic edge and its students have lower achievement compared to other nations. As of 2012, the United States ranked below average in mathematics, and was average in science and reading literacy out of the 65 countries ranked by the Program for International Student Assessment (Chappell, 2013). Something had to be done to science education to help bridge the gap and return the United States to the top.

As a result, a non-profit organization called Achieve has taken ideas from the National Research Council (NRC) Framework for Science Education (National Research Council (U.S.). Committee on a Conceptual Framework for New K-12 Science Education Standards., & ProQuest (Firm), 2012) and put together a document called the Next Generation Science Standards. These new standards focus on coordinating between the science subject areas of life, physical and earth and space science and preparing students for college and their careers. The NGSS have fewer standards and shifts the focus to the big ideas, rather than the smaller, isolated facts (Stage, Asturias, Cheuk, Daro, & Hampton, 2013). Many believe that one of the reasons the United States is falling behind is because of the way science is being taught in our schools. The Next Generation Science Standards are an attempt to address that concern and assist in the process of correcting it.

In today's society, a majority of occupations utilize science and math in some way or another. Therefore, all students should be engaged in a science curriculum that is rigorous and adaptable for all future career paths. All students need to learn at high levels, no matter in what kind of future education in which they plan to enroll (Feldmann, 2017). Science educators also has the task of producing science-literate adults. Many of the skills that today's adults need to be proficient in order to be able to make healthy and meaningful decisions are learned within a science curriculum (NGSS Lead States, 2013). The Next Generation Science Standards are designed in an effort to give all students access to these skills.

These Next Generation Science Standards include several important changes, when compared to previous sets of standards including the National Science Education Standards (National Research Council, 1995) which were the basis for our previous Iowa Core Curriculum Science Standards. NGSS focuses on the interconnectedness of science that extends well beyond science content. There are three primary dimensions: how to DO science (Science and Engineering Practices), the big science ideas (Disciplinary Core Ideas), and the interconnections (Crosscutting Concepts) among all aspects of science. The performance expectations developed in NGSS do not separate each of these dimensions into their own "units" or "courses" but rather demonstrate how to bring them all together. By bringing all of these items together, science education is meant to be less about memorizing facts and more about the ability to understand and apply what students are learning. NGSS calls this three-dimensional learning. The Next Generation Science Standards are written as performance expectations that focus on what students should be able to do, rather than what they should know.

With the implementation of these new standards into the classroom, there is a need to develop new assessments—ones that engage students in each of these three dimensions (Cooper, 2013). The purpose of this creative component project is to develop writing prompt assessments as one type of assessment that can draw upon all three dimensions. As mentioned in Chapter 1, the NGSS performance expectations are not a set in stone way to teach science. They are simply descriptions of things teachers should assess students on; what they know and are able to do. The NGSS Standards still provide teachers the freedom to decide what their lessons look like, as well as what their assessments look like. With this freedom, and new guidance on what science education should look like, teachers across the United States are tasked with developing appropriate new assessments. The assessments developed throughout this project represent one type of assessment that could be used.

The Benefits of Formative Assessment

When discussing assessments, one is considering any activity that teachers use to get information about their students' learning as well as the teacher's instructing. There are two primary types of assessments: formative and summative. Formative assessments, often referred to as assessments "for" learning, are any assessments given throughout the instruction. The intent of these types of assessments are to inform the teacher of the current level of student understanding so that the teacher can make instructional decisions appropriately and adapt their instruction as needed to meet the needs of their students (Black & William, 1998). Summative assessments, often referred to as assessments "of" learning, are any assessments given at the end of instruction. Often these assessments are given for the main purpose of reporting grades.

When I began work on this project, I considered the writing prompts I wanted to develop as summative assessments. These were questions I could pose at the end of a unit to determine if my students were proficient or non-proficient on the aligned performance expectation(s). As my project developed, however, my plan for the assessments shifted. I now plan to use them as formative assessments. I mentioned in Chapter 1 that my school is an MTSS and a PLC school.

These two characteristics imply that teachers in my school collect a lot of data from formative assessments and use that data in collaborative teams to make decisions about interventions for our students. Often we think of these interventions as being additional opportunities for struggling students to improve, but interventions can also be additional opportunities for advanced students to expand upon their knowledge.

With the work that was put into this project, with its focus on three-dimensional learning, and the development of objective rubrics to measure student success, the writing prompt assessments presented in this report could easily be used to pinpoint specific components of a performance expectations that students are proficient in, as well as other components where they might not be. I should not wait until the end of my instruction and then have students complete these prompts. They should be used throughout my instruction. With the data collected from these writing prompts, not only can I make instructional decisions, I can provide detailed, and meaningful feedback to my students. This feedback can help them adjust their expectations as well, realizing what parts they know well in addition to any parts they maybe need to get extra help with. Using these assessments in this manner, student learning can be significantly improved (Keeley, 2008). In the future, as more writing prompts are developed, with multiple prompts for each performance expectation, I could begin to use these assessments in a summative manner as well, to help make my assessment strategies congruent throughout my instruction, but for now I expect to use them as formative assessments.

Why Have Students Write?

Why writing prompt assessments? The Common Core State Literacy Standards call for students to be able to write arguments based on claims, reasoning, and evidence (Stage, Asturias, Cheuk, Daro, & Hampton, 2013). This is true across all content areas. Throughout my education into science teaching practices, I have heard numerous times the need to have students produce claims, reasoning and evidence. Writing prompts provide an efficient avenue to combine all three dimensions of NGSS with expectations of the Common Core Literacy Standards as well. In fact, when writing the NGSS, Achieve specifically set out to provide links among other disciplines in our educational system. They worked to create connections between their standards and the new Common Core State Standards in literacy, arts, and mathematics that have also been adopted within the Iowa Core (National Research Council of the National Academies, 2014). They want educators to purposefully include these connections in their classrooms. Not only will students be drawing upon their literacy skills within these writing prompts, there will be questions that incorporate their mathematics skills as well, as they are asked to draw conclusions from data provided, both quantitative and qualitative, and in charts and graphs.

There are several other reasons educators might choose to use writing prompts in their evaluation of student understanding. One such reason is that students must construct responses, rather than simply select responses. Beyond the content of the curriculum, teachers are asked to provide students with opportunities to learn problem solving and decision-making skills to prepare them for their out of the classroom experiences (Reiner, Bothell, Sudweeks, & Wood, 2002). By asking students to construct their own responses, students must draw on these skills to determine what information they have learned that may be appropriate for their response and how it connects. Often times, writing prompt responses highlight issues in students' thinking processes, allowing the teacher to then address and help students overcome said issues. This process helps to better prepare students to use those skills outside of the classroom. As adults, students are often going to be asked to organize and communicate their thoughts. They will not be given suggested answers from which they choose their responses (Clay, Selected Response (KSDE Assessment Literacy Project), 2001).

Well-written writing prompts can also provide better insight into what students know. Not all writing prompts are created equal. Writing prompts have the ability to provide the educator with insight into their students' abilities within the upper reaches of Bloom's revised taxonomy (Anderson, et al., 2001) including those of analyzing, evaluating and creating (Reiner, Bothell, Sudweeks, & Wood, 2002) when written correctly. When developing writing prompts, it is also easy to connect the science and engineering principles from the Next Generation Science Standards (Achieve, Inc., 2013).

When reading the Next Generation Science Standards each performance expectation is written to incorporate the three dimensions (SEPs, DCIs and CCCs) into that PE. There are also evidence statements that identify what student proficiency within that PE would look like (what students should know, understand or be able to do). These notes help to provide direction when developing NGSS-linked writing prompts (NGSS Lead States, 2013). An example is shown below in Figure 2.

HS-PS1-5
Students who demonstrate understanding can: **HS-PS1-5.** **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [*Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]
The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	**PS1.B: Chemical Reactions** • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Observable features of the student performance by the end of the course:			
1	Articulating the explanation of phenomena		
	a	Students construct an explanation that includes the idea that as the kinetic energy of colliding particles increases and the number of collisions increases, the reaction rate increases.	
2	Evidence		
	a	Students identify and describe* evidence to construct the explanation, including:	
		i.	Evidence (e.g., from a table of data) of a pattern that increases in concentration (e.g., a change in one concentration while the other concentration is held constant) increase the reaction rate, and vice versa; and
		ii.	Evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa.
3	Reasoning		
	a	Students use and describe* the following chain of reasoning that integrates evidence, facts, and scientific principles to construct the explanation:	
		i.	Molecules that collide can break bonds and form new bonds, producing new molecules.
		ii.	The probability of bonds breaking in the collision depends on the kinetic energy of the collision being sufficient to break the bond, since bond breaking requires energy.
		iii.	Since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds.
		iv.	At a fixed concentration, molecules that are moving faster also collide more frequently, so molecules with higher kinetic energy are likely to collide more often.
		v.	A high concentration means that there are more molecules in a given volume and thus more particle collisions per unit of time at the same temperature.

Figure 1 HS-PS1-5

This figure demonstrates the kind of information provided to the teacher within the Next

Generation Science Standards. Each performance expectation identifies what students need to be able to do to demonstrate proficiency. Figure 2 shows HS-PS1-5 "Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs." It also identifies the linked Science and Engineering Practice (Constructing Explanations and Designing Solutions), Disciplinary Core Idea (PS1.B: Chemical Reactions), and the Crosscutting Concept (Patterns) to assist in developing instruction and assessments that utilize all three dimensions. In addition to this information, the evidence statements indicate observable features that students should be able to do by the end of instruction. These statements provide suggestions for the wording of the question(s) in a writing prompt and/or criteria to include on a rubric developed to assist in the assessment of the writing prompt.

Limitations of Writing Prompts

There are also limitations to writing prompt-type questions as an assessment tool. Because of their time-consuming nature (for both students and teacher), only a few questions could be included on a standard test. While the plan for this project is to develop a group of questions that address many of the performance expectations within the high school physical science grouping of NGSS, the writing prompts will not be the only method of assessment that will be used in my classroom. Students benefit greatly from a variety of assessment strategies used in the classroom to address each of their own learning styles and strengths (California State University, 2015).

A second limitation in using writing prompts is the difficulty in grading such questions. This limitation will be addressed by developing grading rubrics to assist the evaluation process. By definition, a writing prompt should be written so that students are creating their own responses. It is not just a question that has one correct answer that happens to be long. This makes the evaluation process definitively subjective (Reiner, Bothell, Sudweeks, & Wood, 2002). By developing a rubric, this project hopes to make the process more objective, while also allowing for subjective judgement of the quality of student's unique replies as well.

A final limitation to the use of writing prompts to assess performance expectations is that this type of assessment places a lot of weight on students' written communication skills. In today's classrooms, this puts some students at a serious disadvantage (Reiner, Bothell, Sudweeks, & Wood, 2002). While being able to communicate through writing is a necessary component in many paths that students will take in their future, their ability to write is not necessarily what is being assessed in this setting. Their understanding of the big ideas and their interconnectedness is. The avenue of communication should not be an obstacle in the way of the student demonstrating their level of proficiency. As is the case with all classroom activities, assessments would need to be differentiated and student needs would need to be kept in mind at all times. Written communication is often the first choice because multiple students can easily be engaged in the evaluative process at the same time, whereas with oral communication there are limits. These questions could also be provided orally, should the situation warrant this type of differentiation. If the student understands the content matter, the method of communication should not matter.

Writing Effective Writing Prompts

An effective writing prompt is a constructed response type of question. It requires students to generate their responses on their own. A high quality writing prompt does not ask students to simply recall facts and earn full credit. They are often asked to demonstrate understanding at varied levels of Bloom's Revised Taxonomy and must create, evaluate, analyze, and apply, in addition to showing their understanding and remembering facts (Anderson, et al., 2001).

Therefore, an effective, well-written response to a writing prompt can be a performance assessment. Performance assessments do not have to be labs or projects or presentations. Those are reasonable examples of performance assessments, but they are not an exhaustive list. A performance assessment is any assessment that demonstrates student proficiency of a performance expectation. The Next Generation Science Standards defines performance expectations as what students should be able to do in order to demonstrate they have met the standards. These performance expectations help to guarantee that teachers are using the same clear and specific targets for curriculum, instruction and assessment (NGSS Lead States, 2013). If a writing prompt is written well, it provides opportunities for students to demonstrate their understanding of the three dimensions of the Next Generation Science Standards and allows teachers to assess student proficiency on the performance expectations authentically (Clay, Constructed Response (KSDE Assessment Literacy Project), 2001).

There are a few things that one must consider when deciding to utilize writing prompts as an assessment strategy. Students need to be taught how to construct a high-quality response. As a component of this project, I plan to develop rubrics for each question. I can use these rubrics to help students understand how to construct their responses to this type of question. There are several performance expectations that would be early in the year for which I have written multiple writing prompts. It would be beneficial to students to practice before using one of these questions as an assessment tool. Students could be given a copy of a rubric and a question and asked to respond, using the rubric as a guide. They could peer evaluate their responses, again using the rubric as a tool. The teacher should also give specific feedback again, using the rubric. The rubric format that I have developed is congruent from question to question, with the specifics being all that changes. If students are familiar with the format of how they will be assessed they can garner greater success (McTighe & O'Connor, 2005). Similarly, because this style of question lends itself to the higher reaches of Bloom's Taxonomy nicely, teachers need to talk about the verbs they are going to use and what each of them means. What does it mean to persuade or justify or discuss (Clay, Constructed Response (KSDE Assessment Literacy Project), 2001)? The revised Bloom's Taxonomy identifies six increasingly more complex and challenging types of thinking including remembering, understanding, applying, analyzing, evaluating, and creating. The eight prompts developed currently within this project ask students to apply knowledge, to analyze data or claims, and to create things such as models. Future prompts, especially those aligned with HS-PS4, will ask students to evaluate resources provided to them. All of these are within the higher reaches of Bloom's Taxonomy.

Once students are prepared, one must consider the approach they will use in developing the writing prompts to make sure they are developing high quality writing pro determine the quality of the writing prompts developed. A four-step process for writing these type of questions was developed by the Northern Nevada Writing Project, headed by Kristi Pettengill and used at annual summits where elementary, middle school and high school teachers gather to learn about using constructed response questions as a learning tool. A document she prepared is included in Appendix D. Summarizing her four steps, you should: 1. Identify the standard you are assessing. Write your question to match the standard. 2. Connect your question to Bloom's Taxonomy. Aim for the higher levels of thinking. 3. Write your question and make sure it is answerable. 4. Practice writing a response or have a colleague do it for you (Pettengill, 2006).

Another resource on writing effective test questions comes from the Kansas Curriculum Center. In it, the author provides six suggestions for writing essay questions. Summarizing these suggestions, you should: 1. Write the question with a well-defined task. Make sure the student knows exactly what they need to do. 2. Consider the length and quantity of your questions. It can be better to provide multiple questions of shorter length than one or two questions of longer length. 3. Don't give students choices. By providing choices, students receive different tests! 4. Use Bloom's Taxonomy and give a range of levels. Don't give multiple questions on the same test that are all at the same level. 5. Figure out how you plan to score to maintain consistency. 6. Prepare your students (Clay, Selected Response (KSDE Assessment Literacy Project), 2001). Both of these resources were used to create a new tool that is targeted at developing the writing prompts that are the focus of this project. This tool will be discussed more in Chapter 3.

Determining the Quality of Developed Writing Prompts

Once developed, it is important to determine the quality of the writing prompts written. One resource that is helpful in this process is the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric (NGSS Lead States, 2016). This rubric was developed to assist curriculum development experts and educators in developing and selecting high quality NGSS curriculum. The EQuIP rubric is meant to help educators determine how well a lesson or unit aligns with NGSS including three-dimensional learning. The EQuIP rubric is divided into three categories: NGSS 3D Design, NGSS Instructional Supports, and Monitoring Student NGSS Progress. Components of each of these categories, especially the third category would be a helpful tool for determining the quality of the writing prompts developed throughout this project. A copy of the EQuIP rubric can be found in Appendix F. The EQuIP rubric was consulted in the development of a tool that could be used in this project to determine the quality of the writing prompts developed. This rubric is targeted at assessments rather than lessons or complete units. This tool will be discussed more in Chapter 3.

Assessing Student Responses to Writing Prompts

When assessing students' responses to writing prompts given in the past, I did not have a thought-out plan for evaluation and it was difficult to remain objective. In my research on developing well-written writing prompts, I came across the following statement: "When the intended learning outcomes are best indicated by performances – things students would do, make, say, or write – then rubrics are the best way to assess them (Brookhart, 2013)." Responding to the writing prompts developed in this project is a performance assessment, so rubrics are a logical tool for evaluating students' written responses. A rubric is the answer to my issues in evaluating my students' responses.

In preparing a rubric, one must consider two big ideas: what is the set of criteria that is expected from one's students and what would different levels of proficiency look like for each criterion (Brookhart, 2013)? When these two aspects are incorporated into a rubric, then the teacher utilizing it is no longer subjectively judging the student's performance. Rather they are matching their performance to the description provided. Once these two ideas are addressed, one should then consider what type of rubric to use – an analytic rubric or a holistic rubric. An analytic rubric is one where the evaluator considers each of the criteria selected individually. A holistic rubric considers all criteria together. The table below compares the two.

Advantages and Disadvantages of Different Types of Rubrics

Type of Rubric	Definition	Advantages	Disadvantages
Holistic or Analytic: One or Several Judgments?			
Analytic	• Each criterion (dimension, trait) is evaluated separately.	• Gives diagnostic information to teacher. • Gives formative feedback to students. • Easier to link to instruction than holistic rubrics. • Good for formative assessment; adaptable for summative assessment; if you need an overall score for grading, you can combine the scores.	• Takes more time to score than holistic rubrics. • Takes more time to achieve inter-rater reliability than with holistic rubrics.
Holistic	• All criteria (dimensions, traits) are evaluated simultaneously.	• Scoring is faster than with analytic rubrics. • Requires less time to achieve inter-rater reliability. • Good for summative assessment.	• Single overall score does not communicate information about what to do to improve. • Not good for formative assessment.
Source: From Assessment and Grading in Classrooms (p. 201), by Susan M. Brookhart and Anthony J. Nitko, 2008, Upper Saddle River, NJ: Pearson Education. Copyright 2008 by Pearson Education. Reprinted with permission.			

The aim with the development of this project is to be able to use these prompts in both formative and summative settings. The table above would suggest that an analytic rubric is well-suited for formative assessments, and that holistic rubrics are well-suited for summative assessments. When evaluating student responses, whether in a formative setting or summative setting, my purpose is to measure student proficiency and to identify needs for interventions, if necessary. It’s not a big-picture evaluation, but a zoomed-in evaluation, so that I can identify what learning areas I need to target more specifically with each of my students. For these reasons an analytic rubric seems to be the best fit for this project and its goals.

When developing a rubric, one must also differentiate between general and task-specific rubrics. The goal of these rubrics is to help any teacher that might use the writing prompt to fairly and efficiently evaluate their students' work. A general rubric is one that would work for multiple writing prompts. It does not give specific answers but rather describes characteristics that would apply to all. Because of this, it can be shared with students, which is something that can be valuable to students (Brookhart, 2013). A task-specific rubric would focus more specifically on each individual writing prompt and could contain answers to the question. When initially building rubrics for this project, the ones I built were more task-specific, but now my aim is to build a kind of hybrid of the two types of rubrics. I would like to build a general rubric I can share with students about their writing process for the writing prompt. However, in the teacher's notes I would like to give some task-specific suggestions as well to facilitate the grading process of the varying levels of content understanding for each prompt.

Connecting the Performance Expectations to Writing Prompts

One of the first steps I took in developing this process was a verb analysis of the targeted PS1 NGSS performance expectations to determine which performance expectations be best aligned with my project. I later went back and completed this for PS2, PS3 and PS4. My project would not be very successful if the performance expectations could not be answered using written communication. When analyzing the verbs, I discovered that the verbs identified the corresponding Science and Engineering Practice for that performance expectation. With each SEP identified, I ruled out any performance expectations that focused on SEP 3: Planning and carrying out and investigation, or SEP6: Designing solutions (for engineering). This verb analysis is shown below:

HS-PS1 Matter and Its Interactions

HS-PS1-1	**Use** the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.	SEP 2: Developing and using models	"Use" is a verb that can be completed in writing. The student would have to explain how the periodic table tells them the valence electrons and then use that information to predict properties of the element given.
HS-PS1-2	**Construct and revise** an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.	SEP 6: Constructing explanations (for science) and designing solutions (for engineering)	This PE would easily adapt into a writing prompt style question. Writing is a logical way to show an explanation. This would also work orally for students that struggle with written expression.
HS-PS1-3	**Plan and conduct** an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	SEP 3: Planning and carrying out an investigation. *	This PE would be difficult to assess using an essay question. The student has to do an investigation. Therefore this PE will not be used in this project.
HS-PS1-4	**Develop** a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.	SEP 2: Developing and Using Models	This question could look something like, "Penelope is trying to figure out…. Draw a picture that would help illustrate what happens and explain why you drew it the way you did." This would be especially nice for visual learners.

HS-PS1-5	**Apply** scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	SEP 6: Constructing explanations (for science) and designing solutions (for engineering)	Again, asking students to provide an explanation works nicely in a written response. For this particular PE students would need to consider their past experiences in class or outside of class to provide evidence to justify their explanation. I would probably separate the two factors into two separate writing prompts – one on the change of temperature and another on the concentration of the reacting particles. My instruction of this concept already has students applying the big ideas of reaction rates to real-life examples like why a wooly mammoth can be found perfectly preserved with little to no decay).
HS-PS1-6	**Refine** the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.	SEP 6: Constructing explanations and designing solutions	This PE could be written as a question like, "A pharmaceutical factory wants to increase its production of acetaminophen. They have called upon you for a consultation. After evaluating their current setup, what would you recommend to them going forward?" A recommendation is something that can be fulfilled through writing.
HS-PS1-7	**Use** mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	SEP 5: Using mathematics and computational thinking.	This PE combines mathematics and writing. Students must do some math, or look at math already done, and then write about it to support a claim.
HS-PS1-8	**Develop** models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.	SEP 2: Developing and using models.	This PE doesn't directly ask for a written product. However, a writing prompt could ask them to develop a model and then explain how it applies to the situation.

HS-PS2 Motion and Stability: Forces and Interactions (FUTURE WRITING PROMPTS)

HS-PS2-1	**Analyze** data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration.	SEP 4: Analyzing and Interpreting Data	In order to support a claim, students must be able to communicate their thoughts. A written response to a writing prompt would work well for this PE.
HS-PS2-2	**Use** mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	SEP 5: Using mathematics and computational thinking	Again, students are asked to support a claim. Students must be able to communicate their thoughts. A written response to a writing prompt would work well for this PE.
HS-PS2-3	**Apply** scientific and engineering ideas to **design, evaluate and refine** a device that minimizes the force on a macroscopic object during a collision.	SEP 6: Constructing explanations (for science) and designing solutions (for engineering)	This PE would be difficult to assess using a writing prompt. The student has to construct a device. Therefore this PE will not be used in this project.
HS-PS2-4	**Use** mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	SEP 5: Using mathematics and computational thinking	Students here are asked to describe and predict based on mathematical representations. This would align itself with a written response.
HS-PS2-5	**Plan and conduct** an investigation to provide evidence that a changing magnetic field can produce an electric current	SEP 3: Planning and carrying out an investigation. *	The student has to do an investigation. Therefore this PE will not be used in this project.
HS-PS2-6	**Communicate** scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.	SEP 8: Obtaining, evaluating, and communicating information.	This PE can be assessed through writing, however the purpose of this project is to produce in-class type assessments. This one would take longer to produce, using resources other than what I can provide. Therefore this PE will not be used in this project.

HS-PS3 Energy (FUTURE WRITING PROMPTS)

HS-PS3-1	**Create** a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	SEP 5: Using Mathematics and Computational Thinking	This PE asks students to create a computational model and use it to calculate a change in energy. This could be easily be done with a real-life situation and could be done within a writing prompt format.
HS-PS3-2	**Develop** and **use** models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).	SEP 2: Developing and using models.	This PE doesn't directly ask for a written product. However, a writing prompt could ask them to develop a model and then explain how it applies to the situation.
HS-PS3-3	**Design, build, and refine** a device that works within given constraints to convert one form of energy into another form of energy.*	SEP 6: Constructing Explanations and Designing Solutions	This PE does not work for a writing prompt style assessment. I could ask students to write about a device that they had previously created and explain how/why it worked to convert one form of energy into another, but as written this PE doesn't fit my assessment profile and will not be used in future developments of this project.
HS-PS3-4	**Plan and conduct** an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	SEP 3: Planning and carrying out an investigation. *	The student has to do an investigation. Therefore this PE will not be used in future developments of this project.

HS-PS3-5	**Develop and use** a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	SEP 2: Developing and using models.	This PE doesn't directly ask for a written product. However, a writing prompt could ask them to develop a model and then explain how it applies to the situation.

HS-PS4 Waves and their Applications in Technologies for Information Transfer (FUTURE)

HS-PS4-1	**Use** mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media	SEP 5: Using Mathematics and Computational Thinking	Supporting a claim aligns nicely with my goal of developing writing prompts.
HS-PS4-2	**Evaluate** questions about the advantages of using a digital transmission and storage of information.	SEP 1: Asking Questions and Defining Problems	Evaluation of questions is something a student can do within a writing prompt style assessment. This PE could be used for future developments of this project.
HS-PS4-3	**Evaluate** the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.	SEP 7: Engaging in Argument from Evidence	Evaluation of claims, evidence and reasoning is something a student can do within a writing prompt style assessment.
HS-PS4-4	**Evaluate** the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.	SEP 8: Obtaining, Evaluating and Communicating Information	For a writing prompt assessment of this PE I envision finding articles or short texts on the topic and having students respond about the validity and reliability. This would work in this style of assessment.
HS-PS4-5	**Communicate** technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*	SEP 8: Obtaining, Evaluating and Communicating Information	Communication is the main objective of this PE and communication in written form is the main objective of this project.

Through this verb analysis, eighteen performance expectations have been designated as aligning with this project's plan to develop student writing prompts as an assessment strategy aligned with the Next Generation Science Standards and six have been designated as not aligning, as written. This project will go through the development of eight writing prompts that match some of the PEs that align with writing prompts, with a plan to continue developing additional prompts after submission of this project. In Chapter 3 you will find student and teacher copies of these writing prompts, including grading rubrics for each. The teacher's notes will highlight the writing prompt in terms of a) performance expectation, b) science and engineering practice, c) cross-cutting concept, d) disciplinary core idea, and e) authentic vocabulary important to the writing prompt.

Chapter 3

Project

As summarized in Chapter 2, the aim of this project is to develop high quality writing prompt assessments to be used to assess the Next Generation Science Standards in a ninth grade Physical Science classroom. In order to make sure that the writing prompts developed in this project are meaningful, and well-written questions, a tool was developed to help guide some of the decision-making processes as each prompt was written. "Developing Quality Writing Prompts: A Teacher Tool" was created using ideas from the NGSS Foundation Boxes and Evidence Statements (NGSS Lead States, 2013), the Kansas Curriculum Center, and the Northern Nevada Writing Project, each of which was discussed in Chapter 2. This tool is shown below:

Developing Quality Writing Prompts: A Teacher Tool

NGSS Performance Expectation this prompt assesses:		
NGSS dimensions assessed:	Science and Engineering Practice(s):	
	Disciplinary Core Idea(s):	
	Crosscutting Concept(s):	
Connected real-world application		
Bloom's taxonomy level(s) addressed:	Remembering Applying Evaluating	Understanding Analyzing Creating
Draft of prompt		
Is the questions answerable?	Yes	No
What is the expected task the student should complete in answering the question as written?		
Draft of sample response (Can be done by yourself or a colleague)		

Figure 3

An additional tool that was developed during the completion of this project is titled "Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist". The EQuIP Rubric for Lessons and Units was used to create this checklist that focuses strictly on the development of quality assessments through this project. The original EQuIP rubric was developed to measure how well lessons and units are designed to meet the Next Generation Science Standards. There are two components to the EQuIP rubric: one part that is used to evaluate lessons and units, and a second part that is used solely for units. The second part was not used for the evaluation of the writing prompts developed in this project. Likewise, there are a few parts of the first part that were not applicable. For example, where the EQuIP Rubric mentions "develop and use", the word "develop" was removed because these assessments are a documentation of the students' current understanding of what has already been developed in class. The components of Part I that are applicable were pulled together to form the checklist shown below. Completed checklists are included with each developed writing prompt highlighted later in this chapter. One of the criteria included in the checklist asks if the focus of the assessment is to observe how students makes sense of phenomena (and/or design solutions to problems). A phenomenon can be defined as an observable event in nature or our lives that connects to the NGSS. Students should be working towards explaining the science behind the phenomenon in their own words, trying to figure it out, rather than just learning about it (Helen Maltese, 2016).

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Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: ________________________

Assessment Criteria	**Evidence of Quality**		**Comments**
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved—** Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

Overall Summary Comments:

As discussed in Chapter 3, one of the goals of this project was to develop rubrics to be used to assess each of the writing prompts. Each of these rubrics has two parts. The first part is unique to each prompt, focused on the content that prompt is meant to assess. These rubrics will be shown later in Chapter 3, matched with the prompts they are written for. The second part of the rubric is meant to assess the quality of the written response. This part will be the same for each prompt students are asked to complete and provided to the students prior to their first experiences with writing prompts so they are aware of what is expected of them. This part was modeled after several other writing rubrics that I came across in my research. The first rubric I consulted was a rubric developed for the 9^{th}-10^{th} Grade Writing Common Core State Standards (English Professional Learning Council, 2015). It is a rubric written to assess students' proficiencies in writing argumentatively. It is included in Appendix H. I liked the different proficiency levels they used including "exceptional", "skilled", "proficient" and "developing". They also used "inadequate" but I selected to stop at "developing". I try to incorporate positive language as much as possible into my classroom, and I did not like the negative connotation of the word "inadequate".

The individual criteria that were included in the scientific writing rubric I developed for this project blend criteria from the Common Core rubric for Argumentative Writing, with criteria from a rubric created by Montgomery County Public Schools (IAPS Teachers of Montgomery County Public Schools, 2012), the school that inspired this project from the start with their writing prompts, as discussed in Chapter 1. When I was working on this rubric in the later stages of this project, I came across this rubric by chance. Their goals in writing their writing prompts were similar to my goals with my prompts, so their rubric matched my expectations pretty well. This rubric is found in Appendix I.

Scientific Writing Expectations				
Criterion:	**Exceptional**	**Skilled**	**Proficient**	**Developing**
Completeness	Student has answered all listed components of the prompt, including any optional components	Student's answer addresses most of the listed components of the prompt	Student's answer addresses some of the listed components of the prompt	Student's answer does not align with any of the listed components of the prompt
Accurate use of science vocabulary	Consistently uses accurate science vocabulary to appropriately support ideas	Uses accurate science vocabulary to appropriately support ideas	Uses some science vocabulary to support ideas; at times may be inaccurate	Missing science vocabulary and/or inaccurate usage of the vocabulary
Development of ideas	Clearly develops ideas with complete support/data	Clearly develops ideas with complete support/data	Develops ideas with some support/data	Supports idea
Reasoning	Uses logical reasoning to connect the idea to the supports	Uses logical reasoning to connect ideas to the supports	Uses some reasoning for ideas	Uses unclear reasoning for the supports
Style/Cohesion	Organizes the writing logically and purposefully	Organizes the writing logically and purposefully	Shows an organization plan in the writing	Attempts to organize writing
Grammar and Spelling/ Conventions	Contains minimal errors in conventions that do not interfere with readers' understanding	Contains minimal errors in conventions that may interfere with readers' understanding	Contains errors in conventions that may interfere with some readers' understandings	Contains errors that interfere with the readers' understanding

Writing Prompts

The writing prompts included in this project come from the six performance expectations under HS-PS1 Matter and Its Interactions identified as aligning with the writing prompt format in the verb analysis of Chapter 2. They include:

- HS-PS1-1: "Introducing…Four New Elements!
- HS-PS1-2: "Popcorn Salt"
- HS-PS1-4: "Baking Soda and Vinegar Volcano"
- HS-PS1-4: "Popcorn Salt 2.0"
- HS-PS1-5: "Stained Uniform"
- HS-PS1-5: "Spoiled Milk"
- HS-PS1-7: "Candle Wax"
- HS-PS1-8: "Radon"

Each of the developed writing prompts will include the following materials, found in Chapter 3:

1.) A completed copy of the Developing Quality Writing Prompts: A Teacher Tool form used in the process of creating the prompt

2.) A student copy of the writing prompt

3.) Teacher's notes for the writing prompt including:

a. The SEP(s) addressed

b. The DCI(s) addressed

c. The CCC(s) addressed

d. Important vocabulary students should know to answer the prompt completely

e. A rubric for scoring the content of the prompt (highlighting components of each of the three-dimensions the NGSS are built upon)

f. A completed "Assessing the Quality of NGSS Aligned Writing Prompt Assessments" tool.

Additional materials that are included in the Appendix are sample student responses for previous versions of "Popcorn Salt" (HS-PS1-2) and "Radon" (HS-PS1-8).

Periodic Table: Introducing...Four New Elements!

Developing Quality Writing Prompts: A Teacher Tool

NGSS Performance Expectation this prompt assesses:	HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
NGSS dimensions assessed:	*Science and Engineering Practices: Developing and Using Models: Use a model to predict the relationships between systems or between components of a system* ***Students should know/be able to:*** • Describe how elements are arranged in the periodic table • The structure of the atom, including the positively-charged nucleus that contains protons and neutrons and the electron cloud that contains negatively charged electrons • Determine how many valence electrons there are in a particular element, as well as any patterns associated with this number and the arrangement of the periodic table • Count the number of protons in each element, and describe how elements are arranged on the periodic table, according to this number
	Disciplinary Core Ideas: PS1.A: Structure and Properties of Matter: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states ***Students should know/be able to:*** • Describe trends in reactivity and electronegativity, and the relationship to the attractions of valence electrons to the nucleus • Compare atoms based on size across a row or down a group in the periodic table
	Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ***Students should know/be able to:*** • Predict patterns of behavior of the elements based on the attractions and repulsions between particles • Predict reactivity of an atom based on the number of valence electrons • Predict the number and types of bonds formed by an element and between elements • Predict the number and charges in stable ions that form from atoms in a group of the periodic table
Connected real-world application	Science in the news…new elements discovered/named to complete the periodic table!

Bloom's taxonomy level(s) addressed:	Remembering **Applying** Evaluating	Understanding **Analyzing** Creating
Draft of prompt	In 2016, 4 new elements were discovered: Nihonium (Nh, atomic number 113), Moscovium (Mc, atomic number 115), Tennessine (Ts, atomic number 117), and Oganesson (Og, atomic number 118). This is exciting news because it completes the 7^{th} row of the periodic table (remember how most of the tables we've looked at have weird 3 letter symbols like Uut and Uup down there?)! The Royal Society of Chemistry (yes, that's really a thing!) has asked for your help in predicting what the properties of these new elements might be. They have provided the table below and descriptions of some of the elements shown in an additional document. Use the periodic table as a model to predict as many properties as you can of the four new elements: Nihonium, Moscovium, Tennessine, and Oganesson. Consider the properties that were given for other elements and any other properties that you can predict including reactivity and type of bond they might form with other elements. Explain your reasoning. In your response, be sure to include: • Any models that you draw that help explain your predicted properties. • A discussion of trends that you notice in data given for the other elements. • A description of the subatomic particles that make up the 4 new elements and the purpose of each of those particles, with relation to predicted properties. • A proposed explanation for how scientists knew where to place each of these new elements on the periodic table.	
Is the questions answerable?	Yes	No
What is the expected task the student should complete in answering the question as written?	Students would look for patterns and trends on the periodic table with the known elements and then use those patterns and trends to predict properties of the four new elements.	
Draft of sample response (Can be done by yourself or a colleague)	**Nh:** Physical State – solid, Density >14 g/cm^3, Melting point >303˚C, color – silvery white, atomic radius <180 pm, Ionization Energy <589 kJ/mol, Mass <289 amu **Mc**: Physical State – solid, Density between 12.9 g/cm^3 and 14 g/cm^3, Melting point >271˚C, color – silvery white, atomic radius between 180 pm and 183 pm, Ionization Energy <703 kJ/mol, Mass: between 289 amu and 298 amu	

	Ts: Physical State – solid, Density <12.9 g/cm^3, Color – very dark, Atomic Radius >150 pm, Ionization Energy >723 kJ/mol, Mass >298 amu, This is a halogen **Og:** Physical State – gas, Density >0.00973 g/cm^3, Melting Point >-71˚C, Color – colorless, Atomic Radius >150 pm, Ionization Energy <1037 kJ/mol, Mass >298 amu, This is a noble gas The predicted properties are based on the periodic trends discussed in class. Atomic radius increases from right to left and top to bottom on the periodic table. Ionization energy increases up and to the right. Density increases down and to the left. I compared the elements around it and made my decisions. I mostly looked at the group it landed in. Scientists look at similar properties to find out where to put the elements. They also knew they went there because of their atomic mass. Our job is to try to explain why they put them there.

Student Copy: Introducing…Four New Elements!

In 2016, 4 new elements were discovered: Nihonium (Nh, atomic number 113), Moscovium (Mc, atomic number 115), Tennessine (Ts, atomic number 117), and Oganesson (Og, atomic number 118). This is exciting news because it completes the 7th row of the periodic table (remember how most of the tables we've looked at have weird 3 letter symbols like Uut and Uup down there?)! The Royal Society of Chemistry (yes, that's really a thing!) has asked for your help in predicting what the properties of these new elements might be. They have provided the table below and descriptions of some of the elements shown in an additional document.

	1	2		13	14	15	16	17	18
1	1 H								2 He
2	3 Li	4 Be	Transition Elements (Groups 3-12)	5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg		13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

Use the periodic table as a model to predict as many properties as you can of the four new elements: Nihonium, Moscovium, Tennessine, and Oganesson. Consider the properties that were given for other elements and any other properties that you can predict including reactivity and type of bond they might form with other elements. **Explain your reasoning**. In your response, be sure to include:

- Any models that you draw that help explain your predicted properties.
- A discussion of trends that you notice in data given for the other elements.
- A description of the valence electrons that are in each of the 4 new elements and how they affect the predicted properties.
- A proposed explanation for how scientists knew where to place each of these new elements on the periodic table.

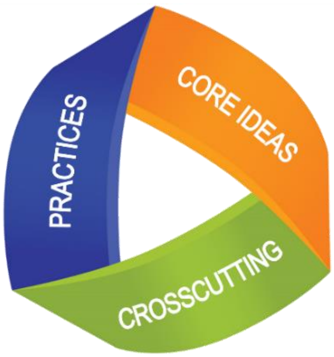
	1	2		13	14	15	16	17	18
1	H Physical State: gas Density: 0.09 g/cm^3 Melting Point: -259 °C Color: colorless Atomic Radius: 31 pm Ionization Energy: 1312 kJ/mol Mass:1.01 amu								He Physical State: gas Density: 0.00018 g/cm^3 Melting Point: -272°C Color: colorless Atomic Radius: 28 pm Ionization Energy: 2372 kJ/mol Mass: 4.00 amu
2	Li Physical State: solid Density: 0.534 g/cm^3 Melting Point: 180°C Color: silver Atomic Radius: 128 pm Ionization Energy: 520 kJ/mol Mass: 6.94 amu	Be Physical State: solid Density: 1.85 g/cm^3 Melting Point: 1287°C Color: gray Atomic Radius: 96 pm Ionization Energy: 900 kJ/mol Mass: 9.01 amu		B Physical State: solid Density: 2.37 g/cm^3 Melting Point: 2075°C Color: black Atomic Radius: 84 pm Ionization Energy: 801 kJ/mol Mass: 10.81 amu	C Physical State: solid Density: 2.10 g/cm^3 Melting Point: 3550°C Color: black Atomic Radius: 76 pm Ionization Energy: 1087 kJ/mol Mass: 12.01 amu	N Physical State: gas Density: 0.00125 g/cm^3 Melting Point: -210°C Color: colorless Atomic Radius: 71 pm Ionization Energy: 1402 kJ/mol Mass: 14.01 amu	O Physical State: gas Density: 0.00143 g/cm^3 Melting Point: -218°C Color: colorless Atomic Radius: 66 pm Ionization Energy: 1314 kJ/mol Mass: 16.00 amu	F Physical State: gas Density: 0.00170 g/cm^3 Melting Point: -219.6°C Color: pale yellow Atomic Radius: 57 pm Ionization Energy: 1681 kJ/mol Mass: 19.00 amu	Ne Physical State: gas Density: 0.00090 g/cm^3 Melting Point: -249°C Color: colorless Atomic Radius: 58 pm Ionization Energy: 2081 kJ/mol Mass: 20.18 amu
3	Na Physical State: solid Density: 0.971 g/cm^3 Melting Point: 98°C Color: silver Atomic Radius: 166 pm Ionization Energy: 496 kJ/mol Mass: 22.99 amu	Mg Physical State: solid Density: 1.74 g/cm^3 Melting Point: 651°C Color: silvery white Atomic Radius: 141 pm Ionization Energy: 738 kJ/mol Mass: 24.31 amu		Al Physical State: solid Density: 2.7 g/cm^3 Melting Point: 660°C Color: silver Atomic Radius: 121 pm Ionization Energy: 578 kJ/mol Mass: 26.98 amu	Si Physical State: solid Density: 2.33 g/cm^3 Melting Point: 1410°C Color: gray Atomic Radius: 111 pm Ionization Energy: 787 kJ/mol Mass: 28.09 amu	P Physical State: solid Density: 1.823 g/cm^3 Melting Point: 44°C Color: pale yellow Atomic Radius: 107 pm Ionization Energy: 1012 kJ/mol Mass: 30.97 amu	S Physical State: solid Density: 1.96 g/cm^3 Melting Point: 113°C Color: bright yellow Atomic Radius: 105 pm Ionization Energy: 1000 kJ/mol Mass: 32.06 amu	Cl Physical State: gas Density: 0.00321 g/cm^3 Melting Point: -101°C Color: greenish yellow Atomic Radius: 102 pm Ionization Energy: 1251 kJ/mol Mass: 35.45 amu	Ar Physical State: gas Density: 0.00178 g/cm^3 Melting Point: -189.2°C Color: colorless Atomic Radius: 106 pm Ionization Energy: 1521 kJ/mol Mass: 39.95 amu
4	K Physical State: solid Density: 0.86 g/cm^3 Melting Point: 63°C Color: silver Atomic Radius: 206 pm Ionization Energy: 419 kJ/mol Mass: 39.10 amu	Ca Physical State: solid Density: 1.57 g/cm^3 Melting Point: 845°C Color: silvery white Atomic Radius: 176 pm Ionization Energy: 590 kJ/mol Mass: 40.08 amu	Transition Elements (Groups 3-12)	Ga Physical State: solid Density: 5.904 g/cm^3 Melting Point: 30°C Color: silvery Atomic Radius: 122 pm Ionization Energy: 579 kJ/mol Mass: 69.73 amu	Ge Physical State: solid Density: 5.32 g/cm^3 Melting Point: 937°C Color: gray Atomic Radius: 120 pm Ionization Energy: 762 kJ/mol Mass: 72.61 amu	As Physical State: solid Density: 5.727 g/cm^3 Melting Point: 81°C Color: bright yellow Atomic Radius: 119 pm Ionization Energy: 947 kJ/mol Mass: 74.92 amu	Se Physical State: solid Density: 4.819g/cm^3 Melting Point: 217°C Color: gray Atomic Radius: 120 pm Ionization Energy: 941 kJ/mol Mass: 78.09 amu	Br Physical State: gas Density: 3.12 g/cm^3 Melting Point: -7.2°C Color: reddish brown Atomic Radius: 120 pm Ionization Energy: 1140 kJ/mol Mass: 79.90 amu	Kr Physical State: gas Density: 0.00374 g/cm^3 Melting Point: -156.6°C Color: colorless Atomic Radius: 116 pm Ionization Energy: 1351 kJ/mol Mass: 84.80 amu
5	Rb Physical State: solid Density: 1.53 g/cm^3 Melting Point: 39°C Color: silvery white Atomic Radius:220 pm Ionization Energy: 403 kJ/mol Mass: 84.49 amu	Sr Physical State: solid Density: 2.54 g/cm^3 Melting Point: 769°C Color: silvery white Atomic Radius: 195 pm Ionization Energy: 550 kJ/mol Mass: 87.62 amu		In Physical State: solid Density: 7.31 g/cm^3 Melting Point: 157°C Color: silvery white Atomic Radius: 142 pm Ionization Energy: 558 kJ/mol Mass: 114.82 amu	Sn Physical State: solid Density: 7.31 g/cm^3 Melting Point: 232°C Color: silver Atomic Radius: 139 pm Ionization Energy: 709 kJ/mol Mass: 118.71 amu	Sb Physical State: solid Density: 6.697 g/cm^3 Melting Point: 630°C Color: silvery white Atomic Radius: 139 pm Ionization Energy: 834 kJ/mol Mass: 121.76 amu	Te Physical State: solid Density: 4.819g/cm^3 Melting Point: 449°C Color: silvery white Atomic Radius: 138 pm Ionization Energy: 869 kJ/mol Mass: 127.6 amu	I Physical State: solid Density: 4.93 g/cm^3 Melting Point: 113.5°C Color: bluish-black Atomic Radius: 139 pm Ionization Energy: 1008 kJ/mol Mass: 126.90 amu	Xe Physical State: gas Density: 0.00585 g/cm^3 Melting Point: -119.9°C Color: colorless Atomic Radius: 140 pm Ionization Energy: 1170 kJ/mol Mass: 131.29 amu
6	Cs Physical State: solid Density: 1.87 g/cm^3 Melting Point: -101°C Color: silvery white Atomic Radius: 244 pm Ionization Energy: 376 kJ/mol Mass: 132.91 amu	Ba Physical State: solid Density: 3.6 g/cm^3 Melting Point: 710°C Color: silvery white Atomic Radius: 215 pm Ionization Energy: 503 kJ/mol Mass: 137.33 amu		Tl Physical State: solid Density: 11.85 g/cm^3 Melting Point: 303°C Color: silvery white Atomic Radius: 145 pm Ionization Energy: 589 kJ/mol Mass: 204.38 amu	Pb Physical State: solid Density: 11.35 g/cm^3 Melting Point: 327.5°C Color: gray Atomic Radius: 148 pm Ionization Energy: 716 kJ/mol Mass: 207.20 amu	Bi Physical State: solid Density: 9.78 g/cm^3 Melting Point: 271°C Color: silvery white Atomic Radius: 148 pm Ionization Energy: 703 kJ/mol Mass: 208.98 amu	Po Physical State: solid Density: 9.16 g/cm^3 Melting Point: 254°C Color: silvery-gray Atomic Radius: 140 pm Ionization Energy: 812 kJ/mol Mass: 208.98 amu	At Physical State: solid Density: 7 g/cm^3 Melting Point: 302°C Color: very dark Atomic Radius: 150 pm Ionization Energy: 890 kJ/mol Mass: 209.98 amu	Rn Physical State: gas Density: 0.00973 g/cm^3 Melting Point: -71°C Color: colorless Atomic Radius: 150 pm Ionization Energy: 1037 kJ/mol Mass: 222.02 amu
7	Fr Physical State: solid Density: 1.87 g/cm^3 Melting Point: 27°C Color: silver-gray Atomic Radius: 260 pm Ionization Energy: 380 kJ/mol Mass: 223.02 amu	Ra Physical State: solid Density: 5.5 g/cm^3 Melting Point: 700°C Color: silvery white Atomic Radius: 221 pm Ionization Energy: 509 kJ/mol Mass: 226.03 amu		Nh	Fl Physical State: solid Density: 14 g/cm^3 Melting Point: 67°C Color: silvery white Atomic Radius: 180 pm Ionization Energy: unknown Mass: 289 amu	Mc	Lv Physical State: solid Density: 12.9 g/cm^3 Melting Point: 364-507 °C Color: gray Atomic Radius: 183 pm Ionization Energy: 723 kJ/mol Mass: 298 amu	Ts	Og

Figure 4: Properties of Known Elements for Use with "Introducing...!"

Teacher Notes: Introducing…Four New Elements!

NGSS/Iowa Core Alignment:

Performance Expectation: HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.



Science and Engineering Practices: Developing and Using Models: Use a model to predict the relationships between systems or between components of a system.

Disciplinary Core Ideas: PS1.A: Structure and Properties of Matter: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) arrangement, atomic number, atomic radius, attraction, charge, covalent bond, density, electronegativity, electrons, group, ion, ionic bond, ionization energy, melting point, metallic bond, negative, neutrons, nucleus, physical state, positive, protons, reactivity, repulsion, row, valence electrons

Assessment Guide: Introducing…Four New Elements!

Criterion:	Exceptional	Skilled	Proficient	Developing
Description of new elements	The student has predicted three or more properties of all four new elements that correctly align with periodic trends	The student has predicted one or two properties of all four new elements that correctly align with periodic trends	The student suggests a few properties of the new elements, but does not specify which element or the properties may have some inaccuracies	There are numerous errors in their description of the new elements
Models	The student has drawn a model(s) and correctly uses it to explain their predictions of the elements' properties	The student has drawn a model and generalizes it for all of the elements. Uses the model to explain their predictions of the elements' properties, with a few errors	The student describes a model and uses it correctly to explain predictions, but it is not drawn.	There are numerous errors in a drawn or undrawn model, or no evidence that a model was considered in preparation of the predicted properties of the elements.
Periodic Trends	Correctly identifies three or more observed trends in element data from their given periodic table	Correctly identifies 1-2 observed trends in element data from their given periodic table	Identifies several observed trends in element data from their given periodic table but has some errors or inconsistencies	Doesn't identify any periodic trends or has numerous errors in trends identified
Explanation	Writes a thoughtful explanation for how scientists knew where to place the new elements that is well developed	Writes an explanation for how scientists knew where to place the new elements	Has some errors in explaining how scientists knew where to place the new elements	Doesn't suggest how scientists knew where to place the new elements

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Introducing…Four New Elements!**

Assessment Criteria	Evidence of Quality		Comments
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	We discuss the recent completion of the periodic table in class (so this is related to their prior experiences to motivate their problem solving)
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	They are being asked to analyze known data and suggest properties of new elements (designing solutions to problems)
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Students are asked to use the periodic table as a model to predict properties of the new elements
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students are analyzing data to determine periodic trends and relating them to valence electrons
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students are applying the patterns they notice on the periodic table to make predictions of properties of new elements.
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	This is based on current events: the 2016 discovery of four new elements that completes the periodic table. It is meaningful and exciting and it shows how scientists are engaged in determining properties even to this day.
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	This writing prompt asks students to **express** themselves (what properties do they predict?), **justify** (explain their prediction), **interpret** (analyze data and draw conclusions from the data), and **represent** (show any models you draw to help explain your predicted properties)
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	The bulleted items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation

• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	On the rubric developed, students are assessed on their model (SEP), their description of the new elements (DCI), and how they identify periodic trends/ explains patterns observed to explain how scientists knew how to place the new elements
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency. To simply be proficient, they must identify a few properties. But there are lots of properties that can discussed, to show that they might be skilled or exceptional. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level.

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed**—Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

Overall Summary Comments:

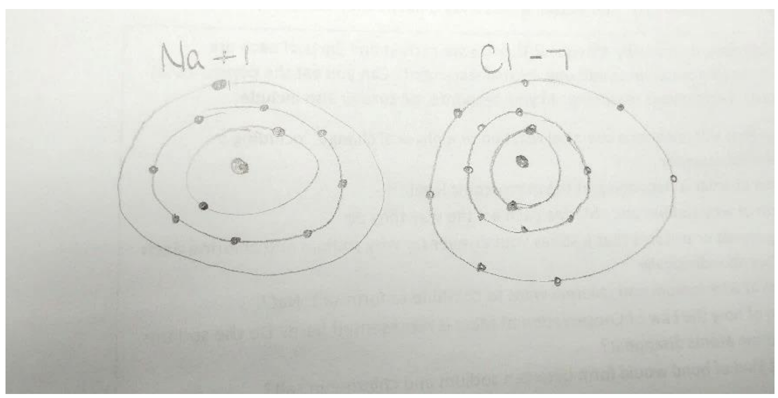
As the years go on, this becomes less-connected to real-life experiences because it will be old news, so the first question will become a no. Students are interested in this now, because it is new news, but may be less engaged in future years. Even with this as a no, this would still rate as an E. Could include a news article with this assessment from the announcement of the elements.

Chemical Reactions: Popcorn Salt

Developing Quality Writing Prompts: A Teacher Tool

<table>
<tr><td>NGSS Performance Expectation this prompt assesses:</td><td>HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties</td></tr>
<tr><td rowspan="3">NGSS dimensions assessed:</td><td>Science and Engineering Practices: Constructing Explanations and Designing Solutions: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the pasts and will continue to do so in the future
Students should know/be able to:
Construct an explanation of the outcome of the reaction between sodium metal and chlorine gas.
Explain that the total number of atoms of each element in the reactants and products is the same
Connect evidence to their reasoning</td></tr>
<tr><td>Disciplinary Core Ideas: PS1.A: Structure and Properties of Matter: The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
PS1.B: Chemical Reactions: The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
Students should know/be able to:
Determine the number and types of bonds that would form in the reaction, using the number of valence electrons and electronegativity in their explanation
Explain why each atom has the number of valence electrons it does, based on their position in the periodic table
Identify products and reactants, and give their corresponding chemical formulas
Compare the number and types of atoms before and after a reaction</td></tr>
<tr><td>Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
Students should know/be able to:
Discuss patterns of attraction on the periodic table and how they can help predict the type of reaction that would occur</td></tr>
<tr><td>Connected real-world application</td><td>How is salt formed? (Real-life chemistry)</td></tr>
</table>

Bloom's taxonomy level(s) addressed:	Remembering Applying Evaluating	Understanding Analyzing Creating
Draft of prompt	Chlorine (Cl_2), a halogen, is found in group 17 on the periodic table. It is known to be extremely violent, and was even used as a deadly poison during World War I. Sodium, (Na) an alkali metal, is found in group 1 on the periodic table. It is also known to be extremely violent, exploding when combined with water. Yet, when combined as shown in the picture below, they fill the net of popcorn above the reaction with a tasty compound we know as salt (NaCl). Two students, Alfred and Theresa watch this reaction take place and have the following conversation: Alfred – No way would I eat that popcorn. Sodium and chlorine?! They're both deadly! I love popcorn, but heck no! I don't want to die. The Law of Conservation of Mass says matter isn't destroyed, so they're still there! Theresa – I'd try it. They said it made salt, right? Salt is in almost everything…it must be safe. Maybe those atoms disappear when they react. The picture shows a fire…maybe they burned up! Parts of each of the statements made by Alfred and Theresa are correct and parts of each are incorrect. Combine their two statements into one, factual statement. Can you eat the popcorn that is salted in this picture? Explain your reasoning. In your response, be sure to also include: • A justification that this is either a chemical reaction or a physical change, including a balanced chemical equation. • An explanation of what is happening at the microscopic level • An explanation of why sodium and chlorine each act the way they do • A model using words or pictures that justifies your answer for why sodium and chlorine each act the way they do individually • An explanation of why sodium and chlorine want to combine to form salt, NaCl. • An explanation of how the Law of Conservation of Mass is represented here. Do the sodium atoms and chlorine atoms disappear? • Optional: What kind of bond would form between sodium and chlorine in salt? Be sure to consider the completeness of your response, supporting details, and accurate use of terms.	
Is the questions answerable?	Yes	No

What is the expected task the student should complete in answering the question as written?	I expect students to recognize this as a chemical change because energy was given off. They should be able to write a balanced equation for the reaction of Na and Cl. They should identify that sodium has one valence electron it wants to lose and that chlorine has seven valence electrons so it wants to gain one. Each one is only one electron away from having a full valence shell so they are very reactive. They should be able to show that the atoms didn't disappear, they just formed bonds and if they show the balanced equation can show that the number of atoms of each element are the same on both the reactant and product sides. If they choose to answer the optional part, they should identify this as an ionic bond.
Draft of sample response (Can be done by yourself or a colleague)	Yes, this popcorn would be safe to eat. Because this is a chemical reaction, the properties of the two elements change. When you combine sodium and chlorine they create a fire which is a proof of a chemical reaction. The Law of Conservation of Mass says that the matter is still there. All of the atoms are still there, they are just now combined as a compound. One way to show the reaction is through the equation $Cl_2 + 2\ Na \rightarrow 2\ NaCl$. At the microscopic level, the atoms are bonding to each other and forming the salt. Sodium has only one valence electron so it wants to lose it really bad and chlorine has seven valence electrons so it wants to gain one really bad. If these elements are combined with certain things they are very reactive stealing/dumping of electrons. When they react with each other they each have full valence shells and are happy. 

Student Copy: Popcorn Salt

Chlorine (Cl_2), a halogen, is found in group 17 on the periodic table. It is known to be extremely violent, and was even used as a deadly poison during World War I. Sodium, (Na) an alkali metal, is found in group 1 on the periodic table. It is also known to be extremely violent, exploding when combined with water. Yet, when combined as shown in the picture below, they fill the net of popcorn above the reaction with a tasty compound we know as salt (NaCl).

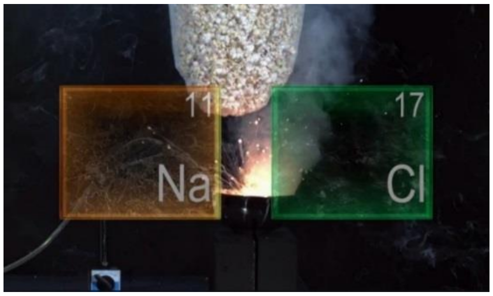


Photo Credit: NOVA: Hunting the Elements www.pbs.org/video/2217713569/

Two students, Alfred and Theresa watch this reaction take place and have the following conversation:

Alfred – No way would I eat that popcorn. Sodium and chlorine?! They're both deadly! I love popcorn, but heck no! I don't want to die. The Law of Conservation of Mass says matter isn't destroyed, so they're still there!

Theresa – I'd try it. They said it made salt, right? Salt is in almost everything…it must be safe. Maybe those atoms disappear when they react. The picture shows a fire…maybe they burned up!

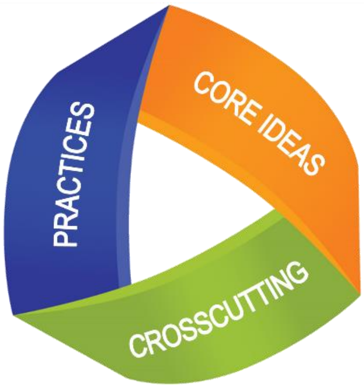
Parts of each of the statements made by Alfred and Theresa are correct and parts of each are incorrect. Combine their two statements into one, factual statement. Can you eat the popcorn that is salted in this picture? Explain your reasoning. In your response, be sure to also include:

- A justification that this is either a chemical reaction or a physical change, including a balanced chemical equation.
- An explanation of what is happening at the microscopic level
- An explanation of why sodium and chlorine each act the way they do
- A model using words or pictures that justifies your answer for why sodium and chlorine each act the way they do individually
- An explanation of why sodium and chlorine want to combine to form salt, NaCl.
- An explanation of how the Law of Conservation of Mass is represented here. Do the sodium atoms and chlorine atoms disappear?
- Optional: What kind of bond would form between sodium and chlorine in salt?

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Teacher Notes: Popcorn Salt

NGSS/Iowa Core Alignment: Performance Expectation: HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.



Science and Engineering Practices: Constructing Explanations and Designing Solutions: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the pasts and will continue to do so in the future.

Disciplinary Core Ideas: PS1.A: Structure and Properties of Matter: The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.B: Chemical Reactions: The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) atom, attraction, chemical properties, chemical reaction, conserved, electronegativity, group, ionic bond, law, nucleus, periodic table, product, protons, reactant, trends, valence electrons

Assessment Guide: Popcorn Salt

Criterion:	Exceptional	Skilled	Proficient	Developing
Balanced Chemical Equation	Identifies and justifies this as a chemical reaction and includes the balanced chemical equation	Identifies and justifies this as a chemical reaction and includes a chemical equation, but made some errors in the balanced equation	Identifies but does not justify this as a chemical reaction, and does not include a balanced chemical equation, nor any evidence that an attempt was made to balance	Incorrectly identifies the reaction as a physical change, or makes no mention of the chemical equation
Model	Has a model for sodium and a separate model for chlorine that explains why each element has its unique properties described in the problem	Describes why each element behaves the way they do, but doesn't have a model to support their description	Has a model or a description that attempts to explain sodium and chlorine's behaviors, but has some errors	Doesn't address why sodium and chlorine behave the ways they do
Explanation of the Outcome of the Reaction	Correctly explains what is happening at the microscopic level, referring to the model they have prepared and why these two elements want to combine to form salt	Correctly explains what is happening at the microscopic level OR why these two elements want to combine to form salt, but not both.	Explains what is happening at the microscopic level OR why these two elements want to combine to form salt, but not both. Explanation has some errors.	Explains what is happening at the microscopic level OR why these two elements want to combine to form salt, but not both. Explanation has many errors OR doesn't address either component.
Law of Conservation of Mass	Addresses the idea that atoms are conserved			Doesn't address the idea that atoms are conserved

Conclusion	Has a statement answering the question “Can you eat the popcorn that is salted in this picture” as Yes, and justifies their response.	Has a statement answering the question “Can you eat the popcorn that is salted in this picture” as Yes, and but doesn’t justify their response.	Has a statement answering the question “Can you eat the popcorn that is salted in this picture” as No, and (incorrectly)justifies their response.	Has a statement answering the question “Can you eat the popcorn that is salted in this picture” as No, and doesn’t justify their response.

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Popcorn Salt**

Assessment Criteria	Evidence of Quality		Comments
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	This writing prompt is asking students to consider what is happening to a reaction that gives off a large amount of energy. My students are motivated by fire (even though they don't actually get to make it here!)
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	Students are asked to explain why (make sense) two reactive elements can combine to form a compound that is relatively safe for consumption
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Students must construct an explanation of what is occurring in the reaction
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students must explain why sodium and chlorine act the way they do, and how matter is conserved
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students explain why sodium and chlorine act the way they do, using the idea of periodic trends and how their position on the periodic table influences their properties
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	Students are making sense of observations
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	Students must **explain** (what is happening, why they act the way they do, why they want to form salt, how the Law of Conservation of Mass is represented), **justify** that this is a chemical reaction, and **represent** their thinking in the form of a model
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	The bulleted items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	Explanation of the Outcome of the Reaction (SEP), Law of Conservation of Mass (DCI), Model (CCC)

• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency that help make this accessible to all students. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level.

<table>
<tr>
<td>Overall ratings:</td>
<td>E: Example of high quality NGSS design—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10)
E/I: Example of high quality NGSS design if Improved—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8)
R: Revision needed—Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6)
N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)</td>
<td>Circle the overall rating below:
E E/I R N</td>
</tr>
</table>

Overall Summary Comments: My students love explosions, so the fact that salt can be created in the fire that is shown will catch their attention. The idea that two reactive elements like sodium and chlorine can combine to make something that is safe to eat will also intrigue them and draw them in. In class we use the example of Hydrogen and Oxygen (two flammable gases at room temperature) combine to form a non-flammable liquid (water) in class. This links nicely to that discussion.

Energy: Baking Soda and Vinegar Volcano

Developing Quality Writing Prompts: A Teacher Tool

<table>
<tr><td>NGSS Performance Expectation this prompt assesses:</td><td>HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.</td></tr>
<tr><td rowspan="3">NGSS dimensions assessed:</td><td>Science and Engineering Practices: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system
Students should know/be able to:
Create a model that represents what is happening to the energy in a chemical reaction</td></tr>
<tr><td>Disciplinary Core Ideas: PS1.A: Structure and Properties of Matter: A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
PS1.B: Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
Students should know/be able to:
Determine which bonds are being broken during a reaction and which bonds are being formed
Explain that potential energy in a chemical system is transferred to kinetic energy in the surrounding (or vice versa) by molecular collisions
Determine the relative potential energies of the reactants and the products.
Explain that the net change of energy within a system is the result of bonds being broken and formed during a reaction</td></tr>
<tr><td>Crosscutting Concepts: Energy and Matter: Changes of energy and matter in a system can be describe in terms of energy and matter flows into, out of, and within that system.
Students should know/be able to:
Identify the chemical reaction, the system, and the surroundings in a situation
Discuss the transfer of energy between systems and their components or a system and its surrounding and explain that the change in energy in the chemical reactions system is equal but opposite to the change in energy of the surroundings.
Show that the release or absorption of energy depends on the changes occurring to the relative potential energies of the reactants and products.
Explain that bonds are broken by putting energy into a system and that bonds are formed by releasing energy into the surroundings
Use the Law of Conservation of Energy to describe the changes in the overall energy of the system and surroundings</td></tr>
</table>

Connected real-world application	Science fair projects, at-home science growing up
Bloom's taxonomy level(s) addressed:	Remembering — Understanding Applying — Analyzing Evaluating — Creating
Draft of prompt	Many of you have constructed baking soda and vinegar volcanos – perhaps as a class activity, maybe for a science fair, or heck—maybe just for fun! (I know I did…but then again, I'm now a science teacher!) At the very least you've probably seen it on TV. If you're a curious soul, maybe you've touched the "lava". Unlike real lava (please don't touch that!!), a baking soda and vinegar volcano's lava feels cool. The chemical reaction that is taking place is shown below: $$NaHCO_3 + CH_3COOH \rightarrow NaCH_3COO + H_2O + CO_2$$ Develop and describe a model that illustrates why the lava in this volcano reaction is cool. Explain your reasoning. In your response, be sure to include: • A justification that this is either an endothermic or an exothermic reaction and a description of the net change in the energy. • An explanation of what is happening at the microscopic level • An explanation of what is happening to the bonds and why • A model using words or pictures that shows what is happening to the energy during the chemical reaction between the baking soda and vinegar • An explanation of how the Law of Conservation of Energy is represented here. What happens to the energy? Be sure to consider the completeness of your response, supporting details, and accurate use of terms.
Is the questions answerable?	Yes — No
What is the expected task the student should complete in answering the question as written?	I expect students to identify this as an endothermic reaction and explain what is happening at the particle level. They should represent what is happening with the energy in words or a picture and explain how the Law of Conservation of Energy is demonstrated.
Draft of sample response (Can be done by yourself or a colleague)	I know the reaction is endothermic because it feels cool. The reaction is taking a lot of energy in that is needed for it to take place. The particles are reacting with each other, breaking the bonds which requires energy to do. When it takes energy in, it removes it from its surroundings so the change in energy of the surroundings decreases and it feels cold. The total amount of energy in the system remains the same (volcano + surroundings), it is just moving around, so the law of conservation of energy is upheld.

<u>Student Copy: Baking Soda and Vinegar Volcano</u>

Photo Credit : https://95acresofsky.wordpress.com/tag/baking-soda-and-vinegar/

Many of you have constructed baking soda and vinegar volcanos – perhaps as a class activity, maybe for a science fair, or heck—maybe just for fun! (I know I did…but then again, I'm now a science teacher!) At the very least you've probably seen it on TV. If you're a curious soul, maybe you've touched the "lava". Unlike real lava (please don't touch that!!), a baking soda and vinegar volcano's lava feels cool. The chemical reaction that is taking place is shown below:

$$NaHCO_3 + CH_3COOH \rightarrow NaCH_3COO + H_2O + CO_2$$

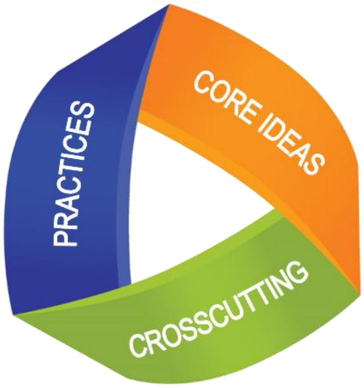
Develop and describe a model that illustrates why the lava in this volcano reaction is cool. Explain your reasoning. In your response, be sure to include:

- A justification that this is either an endothermic or an exothermic reaction and a description of the net change in the energy.
- An explanation of what is happening at the microscopic level
- An explanation of what is happening to the bonds and why
- A model using words or pictures that shows what is happening to the energy during the chemical reaction between the baking soda and vinegar
- An explanation of how the Law of Conservation of Energy is represented here. What happens to the energy?

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Teacher Notes: Baking Soda and Vinegar Volcano

NGSS/Iowa Core Alignment: Performance Expectation: HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.



Science and Engineering Practices: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas: PS1.A: Structure and Properties of Matter: A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B: Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

Crosscutting Concepts: Energy and Matter: Changes of energy and matter in a system can be describe in terms of energy and matter flows into, out of, and within that system.

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) absorption, bond, bond energy, broken, change, chemical reaction, collision, endothermic, energy, exothermic, kinetic energy, Law of Conservation of Energy, model, molecule, net, potential energy, release, surroundings, system, transfer, transformation

Assessment Guide: Baking Soda and Vinegar Volcano

Criterion:	Exceptional	Skilled	Proficient	Developing
Endothermic or Exothermic?	Identifies and justifies this as an endothermic reaction	Identifies and justifies the reaction as endothermic, but justification is incomplete or does not use proper terms	Identifies but does not justify this as an endothermic reaction	Incorrectly identifies this as an exothermic reaction, with or without justification
Net Change	Identifies what kind of net change in energy there was to make the reaction endothermic and correctly explains how that net change came to be	Identifies what kind of net change in energy there was to make the reaction endothermic, but offers no explanation	Incorrectly identifies the kind of net change in energy that occurred	Does not discuss the net change in energy
Model	Creates an appropriate model that shows what is happening to the energy during the chemical reaction	Describes a model but doesn't draw it. Their explanation correctly identifies what is happening to the energy during the reaction	Has a model drawn/described, with multiple errors in what is happening to the energy during the reaction	Does not have a model drawn nor described
Microscopic Level	Correctly explains what is happening to the electrons and bonds during the chemical reaction	Explains what is happening to the electrons OR the bonds during the chemical reaction correctly, but not both	Has some errors in their description of what is happening to the electrons and the bonds during the chemical reaction	Does not describe what is happening to both the electrons nor the bonds
Law of Conservation of Energy	Uses the Law of Conservation of Energy and justifies where the energy went	Mentions the Law of Conservation of Energy but doesn't describe how it is represented in the reaction	Mentions the Law of Conservation of Energy but has some errors in how it is represented in the reaction	Does not mention the Law of Conservation of Energy

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Baking Soda and Vinegar Volcano**

Assessment Criteria	Evidence of Quality		Comments
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	Students prior experiences with homemade volcanoes were the motivation behind this writing prompt
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	Students must explain (make sense) the science behind why the "lava" is cool.
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Students must develop a model that shows what is happening to energy during the reaction
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students explain what is happening at the microscopic level and what is happening to the bonds
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students must justify the reaction as endothermic or exothermic
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	Students are making sense of their observations
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	**Express** (explain what is happening at the microscopic level, explain what is happening to the bonds, explain how the Law of Conservation of Energy is represented), **justify** that the reaction is endothermic, **represent** what is happening in a model
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	The bulleted items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	Model (SEP), Microscopic Level (DCI), Endothermic or Exothermic (DCI), Net Change (CCC)
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency that help make this accessible to all students. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level.

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

Overall Summary Comments: This writing prompt could be prefaced by actually creating the volcano "lava" and letting them feel it. In terms of exothermic and endothermic, my students don't always just trust my word (maybe because I play devil's advocate sometimes to challenge what they already know to be true?). This would help pull in student interest as well.

Energy: Popcorn Salt 2.0

Developing Quality Writing Prompts: A Teacher Tool

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Students should know/be able to:
Determine which bonds are being broken during a reaction and which bonds are being formed
Explain that potential energy in a chemical system is transferred to kinetic energy in the surrounding (or vice versa) by molecular collisions
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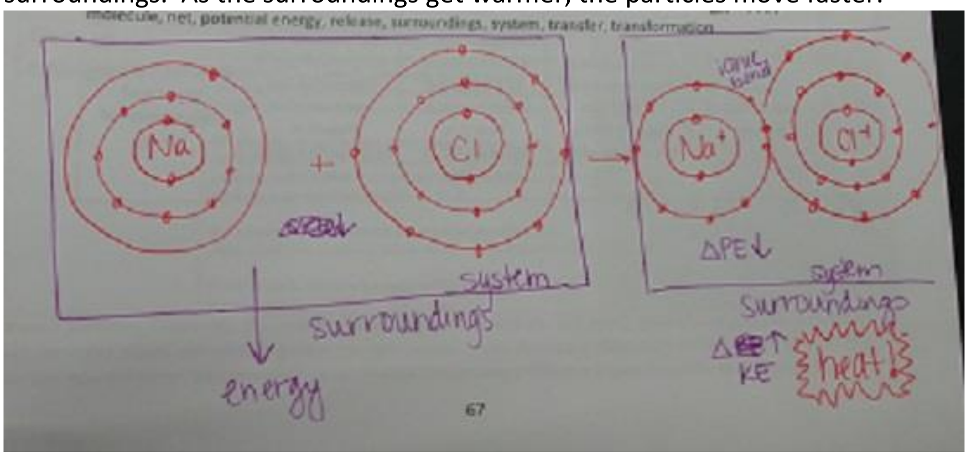
Identify the chemical reaction, the system, and the surroundings in a situation
Discuss the transfer of energy between systems and their components or a system and its surrounding and explain that the change in energy in the chemical reactions system is equal but opposite to the change in energy of the surroundings.
Show that the release or absorption of energy depends on the changes occurring to the relative potential energies of the reactants and products.
Explain that bonds are broken by putting energy into a system and that bonds are formed by releasing energy into the surroundings
Use the Law of Conservation of Energy to describe the changes in the overall energy of the system and surroundings</td></tr>
</table>

Connected real-world application	How is salt formed? (Real-life chemistry)	
Bloom's taxonomy level(s) addressed:	Remembering Applying Evaluating	Understanding Analyzing Creating
Draft of prompt	When sodium (Na) and chlorine (Cl) combine to form salt (NaCl), as shown in the picture to the left, there is a change in energy. Use observation skills, and scientific knowledge to develop a model with the components listed below that illustrates the energy change that occurs in this chemical reaction. Explain your reasoning. Your model must include: • The chemical reaction, the system, and the surroundings under study • The bonds (if any) that are broken during the course of the reaction • The bonds (if any) that are formed during the course of the reaction • The energy transfer between the systems and their components or the system and surroundings • The transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions • The relative potential energies of the reactants and the products In your explanation of your model, be sure to include: • An identification of this reaction as endothermic or exothermic (is the reaction releasing or absorbing energy from its surroundings?). • How the Law of Conservation of Energy is upheld even though there is an obvious energy change in the picture. • A description of what occurs at the particle level that explains why the energy changes.	
Is the questions answerable?	Yes	No
What is the expected task the student should complete in answering the question as written?	To draw a model with all of the components listed and then use that model to determine if the chemical reaction was endothermic or exothermic, explaining what is happening at the microscopic level and identifying how the Law of Conservation of Energy is upheld.	

Draft of sample response (Can be done by yourself or a colleague)	The reaction between sodium and chlorine to produce sodium chloride (salt) is exothermic. This is evidenced by the image of the fire in the picture. When energy is given off, and the surroundings get warmer you have an exothermic reaction. The Law of Conservation of Energy is upheld. Even though the surroundings get warmer, the energy came from within the system. Sodium had one valence electron that it wanted to lose, and chlorine wanted to gain one extra valence electron to complete its valence shell. When these two atoms are allowed to interact and form an ionic bond, the potential energy of the system decreases because both atoms are now in more favorable conditions as ions because they both have full valence shells. This energy, however, doesn't disappear…it simply converts to kinetic energy in the surroundings. As the surroundings get warmer, the particles move faster. 

Student Copy: Popcorn Salt 2.0

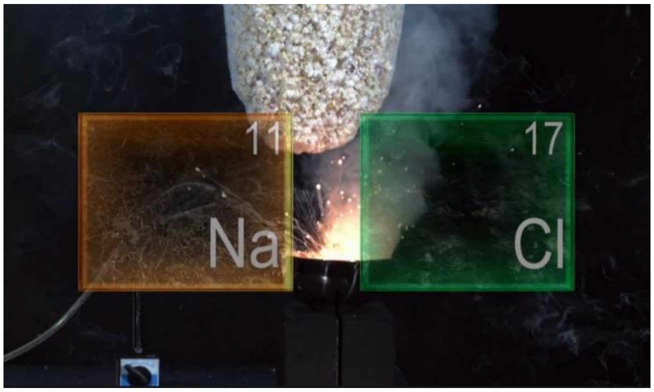


Photo Credit: NOVA: Hunting the Elements
www.pbs.org/video/2217713569/

When sodium (Na) and chlorine (Cl) combine to form salt (NaCl), as shown in the picture to the left, there is a change in energy.

Use observation skills, and scientific knowledge to develop a model with the components listed below that illustrates the energy change that occurs in this chemical reaction. **Explain your reasoning.**

Your model must include:

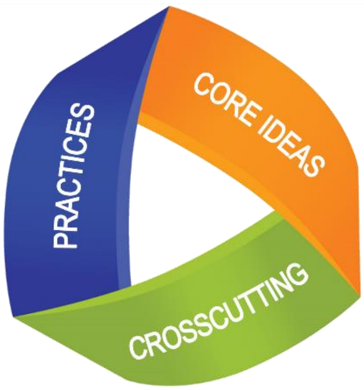
- The chemical reaction, the system, and the surroundings under study
- The bonds (if any) that are broken during the course of the reaction
- The bonds (if any) that are formed during the course of the reaction
- The energy transfer between the systems and their components or the system and surroundings
- The transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions
- The relative potential energies of the reactants and the products

In your explanation of your model, be sure to include:

- An identification of this reaction as endothermic or exothermic (is the reaction releasing or absorbing energy from its surroundings?).
- How the Law of Conservation of Energy is upheld even though there is an obvious energy change in the picture.
- A description of what occurs at the particle level that explains why the energy changes.

Teacher Notes: Popcorn Salt 2.0

NGSS/Iowa Core Alignment: Performance Expectation: HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.



Science and Engineering Practices: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas: PS1.A: Structure and Properties of Matter: A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B: Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

Crosscutting Concepts: Energy and Matter: Changes of energy and matter in a system can be describe in terms of energy and matter flows into, out of, and within that system

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) absorption, bond, bond energy, broken, change, chemical reaction, collision, endothermic, energy, exothermic, kinetic energy, Law of Conservation of Energy, model, molecule, net, potential energy, release, surroundings, system, transfer, transformation

Assessment Guide: Popcorn Salt 2.0

Criterion:	Exceptional	Skilled	Proficient	Developing
Endothermic or Exothermic?	Identifies and correctly and thoroughly justifies this as an endothermic reaction	Identifies reactions as endothermic and provides a somewhat accurate, but not detailed justification	Identifies but does not justify this as an endothermic reaction	Incorrectly identifies this as an exothermic reaction, with or without justification
Model	The model drawn has all six required components included	The model drawn has 4-5 of the required components included	The model drawn has 2-3 of the required components and/or has some errors	The model drawn has fewer than 2 of the required components and/or has many errors
Microscopic Level	Correctly explains what is happening to the electrons and bonds during the chemical reaction correctly	Correctly explains what is happening to the electrons OR the bonds during the chemical reaction correctly, but not both	Has some errors in their description of what is happening to the electrons and the bonds during the chemical reaction	Does not describe what is happening to neither the electrons nor the bonds
Law of Conservation of Energy	Correctly uses the Law of Conservation of Energy and justifies where the energy went	Mentions the Law of Conservation of Energy but doesn't describe how it is represented in the reaction	Mentions the Law of Conservation of Energy but has some errors in how it is represented in the reaction	Does not mention the Law of Conservation of Energy

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Popcorn Salt 2.0**

Assessment Criteria	Evidence of Quality		Comments
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	This writing prompt is asking students to consider what is happening to cause a reaction to give off a large amount of energy. My students are motivated by fire (even though they don't actually get to make it here!)
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	Students have to explain (make sense) the science behind why this reaction gives off so much energy
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Student must develop a model to illustrate the change in energy in the reaction between sodium and chlorine
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students must show how energy is transferred and transformed during the chemical reaction
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students must explain how they know if the reaction is endothermic or exothermic
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	Students must make sense of their observations
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	**Express** (explain their model), **Justify** (explain their reasoning), **represent** (create a model)
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	The bulleted items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	Model (SEP), Microscopic Level (DCI), Endothermic or exothermic (CCC)
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency that help make this accessible to all students. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level.

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed**—Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

Overall Summary Comments: This writing prompt aligns nicely with the SEP, giving them a lot of guidance on what to include in the model without telling them the right answer. I also like how it refers back to a previous prompt so they can see how the same “phenomenon” can be looked at from many different angles to discuss what is going on.

Reaction Rates: Stained Uniform

Developing Quality Writing Prompts: A Teacher Tool

<table>
<tr><td>NGSS Performance Expectation this prompt assesses:</td><td colspan="2">HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.</td></tr>
<tr><td rowspan="3">NGSS dimensions assessed:</td><td colspan="2">Science and Engineering Practices: Constructing Explanations and Designing Solutions: Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects
Students should know/be able to:
Use the relationship between concentration and the number of collisions to explain why higher concentration means bonds are more likely to be broken and formed</td></tr>
<tr><td colspan="2">Disciplinary Core Ideas: PS1.B: Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
Students should know/be able to:
Explain that the collision of molecules can break and form bonds, producing new molecules
Rationalize that the probability of bonds breaking depends on the kinetic energy of the collision and whether or not it is strong enough to break the bonds</td></tr>
<tr><td colspan="2">Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studies and can provide evidence for causality in explanations of phenomena.
Students should know/be able to:
Define the relationship between the amount of kinetic energy, the number of collisions, and the reaction rate
Define the relationship between concentration and the number of collisions</td></tr>
<tr><td>Connected real-world application</td><td colspan="2">Stained uniforms</td></tr>
<tr><td>Bloom’s taxonomy level(s) addressed:</td><td>Remembering

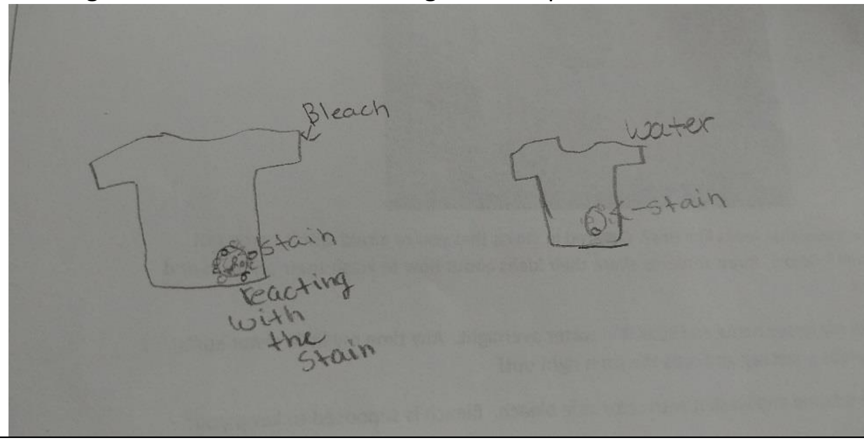
Applying

Evaluating</td><td>Understanding

Analyzing

Creating</td></tr>
</table>

Draft of prompt	Have you ever had a jersey that looks like this? Covered in stains that you're afraid won't come out before your next game? Below, three students share their ideas about how to wash their uniform and get it back to normal! Neal: I'm going to take my jersey home and soak it in water overnight. Any time my little sister spills something, my mom grabs a wet rag and rubs the stain right out! Gina: I'm going to take it home and wash it with color safe bleach. Bleach is supposed to keep your whites bright! Bryon: I'm going to buy one of those color safe Clorox Bleach pens, and rub it right onto the jersey and let it soak. Then wash it like normal. Which student do you think gives the best suggestion for how to get their jersey clean? Apply scientific principles and evidence to provide an explanation. Explain your reasoning. Why won't the others work as well? In your response, be sure to include: • A consideration of the differences at the particle level for the 3 different methods. • An explanation of what happens at the particle level that causes the stain to be removed. • Identification of evidence from other personal experiences in and/or out of class that help explain why you chose that student that you did. • Optional: Provide a model using words or pictures that justifies your answer. Be sure to consider the completeness of your response, supporting details, and accurate use of terms.
Is the questions answerable?	Yes No
What is the expected task the student should complete in answering the question as written?	Students should select one of the given responses and justify why their answer best suggests how to get the jersey clean using the relationship between concentration and reaction rates. They should also explain why the other two will not work (or won't work as well). All three students' suggestions should be mentioned in the response.
Draft of sample response (Can be done by yourself or a colleague)	I feel like Bryon has the best solution with the Clorox pen and letting it soak overnight and then washing it normally. In Neal's idea the water would slowly pull some particles out but not very many. Gina's idea will pull the stains out quicker but wouldn't soak into the stains all the way. Bryon's idea is the best because the cleaner would soak directly into the stains and pull the stain particles out. Bryon's would have the highest concentration of bleach, therefore it is more likely to pull it out because it has the most bleach molecules that can interact with the stain. The more bleach molecules there are, the more collisions there would be between bleach molecules and the stain, and therefore more reaction. Washing it with bleach will have some molecules that can interact, but

	they will have to compete with the water molecules as well. From my experience in art, water just smeared the paint and didn't take it out but soaking in color safe bleach or using a Clorox pen took out the stain. 

Student Copy: Stained Uniform

Photo Credit: https://www.flickr.com/photos/wwworks/6367214815

Have you ever had a jersey that looks like this? Covered in stains that you're afraid won't come out before your next game? Below, three students share their ideas about how to wash their uniform and get it back to normal!

Neal: I'm going to take my jersey home and soak it in water overnight. Any time my little sister spills something, my mom grabs a wet rag and rubs the stain right out!

Gina: I'm going to take it home and wash it with color safe bleach. Bleach is supposed to keep your whites bright!

Bryon: I'm going to buy one of those color safe Clorox Bleach pens, and rub it right onto the jersey and let it soak. Then wash it like normal.

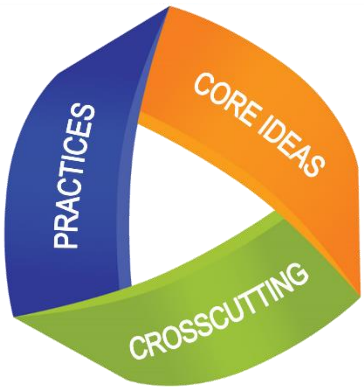
Which student do you think gives the best suggestion for how to get their jersey clean? Apply scientific principles and evidence to provide an explanation. Explain your reasoning. Why is it that the other two ideas don't the others work as well? (Hint: You do not need to know anything about laundry to answer this question.) In your response, be sure to include:

- A consideration of the differences at the particle level for the 3 different methods.
- An explanation of what happens at the particle level that causes the stain to be removed.
- Identification of evidence from other personal experiences in and/or out of class that explain how concentration influences reaction rate. Apply this to your explanation of why you selected the student you did.
- Optional: Provide a model using words or pictures that justifies your answer.

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Teacher Notes: Stained Uniform

NGSS/Iowa Core Alignment: Performance Expectation: HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.



Science and Engineering Practices: Constructing Explanations and Designing Solutions: Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effect.

Disciplinary Core Ideas: PS1.B: Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studies and can provide evidence for causality in explanations of phenomena.

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) bond, colliding particles, collision, concentration, effect, kinetic energy, molecule, particles, probability, rate, reaction, reaction rate

Assessment Guide: Stained Uniform

Criterion:	Exceptional	Skilled	Proficient	Developing
Best Answer	Student correctly identifies Bryon as the student with the best answer and justifies themselves with scientific principles and evidence.	Student correctly identifies Bryon as the student with the best answer, but doesn't justify their response or justification has some flaws in accuracy/reasoning.	Student incorrectly identifies Neal or Gina as the student with the best answer.	The student doesn't select any of the three students as having the best answer.
Particle Level	Uses the relationship between concentration (more particles in the same space) and the number of collisions to explain why higher concentration means reaction will go faster	Tries to explain what is going on at the particle level, but does not describe that higher concentration = more particles = more collisions = faster reaction	Has some errors or omissions in their explanation of what is going on at the particle level	Makes no effort to explain what is going on at the particle level
Personal Experiences	Includes evidence from their personal experiences that correctly align with how concentration affects reaction rate and explains the connection(s)	Brings up personal experiences that are related but does not explain	Brings up personal experiences that are not correctly related	Does not mention any personal connections to the question
Model (optional)	Has a model that correctly justifies their response	Has a model, but it lacks the detail needed to justify their response	Has a model, but aspects of it are incorrect	No model is provided

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Stained Uniform**

Assessment Criteria	**Evidence of Quality**		**Comments**
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	This writing prompt uses a stained uniform to motivate students to make sense of how concentration affects reaction rates
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	This assessment asks students to explain (make sense) why a Clorox pen removes stains better than just water or a wash cycle with bleach
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Students need to construct an explanation using scientific principles to answer the writing prompt question
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students need to explain what is happening at the particle level
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students should identify the relationship that higher concentration = more collisions and more collisions = faster reaction
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	Students are designing solutions, justifying why one of the responses would work better than the others
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	**Express** (explain what happens at the particle level) **interpret** (identify evidence from other personal experiences) **represent** (optional model)
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	The bulleted items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	Best Answer (SEP), Particle Level (DCI and CCC)
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency that help make this accessible to all students. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level.

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

Overall Summary Comments: My intent with asking them to make connections to their past experiences was meant to bring out the idea that higher concentration makes the reaction go faster…in other contexts. They got hung up on having to have past experiences with Clorox pens or getting out stains (I don't know, I don't wash my own clothes!). They also got hung up on not knowing the specific mechanics of how/why bleach gets out stains instead of just thinking about the higher concentration meaning there are more collisions.

Reaction Rates: Spoiled Milk

Developing Quality Writing Prompts: A Teacher Tool

NGSS Performance Expectation this prompt assesses:	HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	
NGSS dimensions assessed:	*Science and Engineering Practices: Constructing Explanations and Designing Solutions: Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects* **Students should know/be able to:** • Use the relationship between temperature and average kinetic energy to explain why higher temperatures means bonds are more likely to be broken and formed	
	Disciplinary Core Ideas: PS1.B: Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **Students should know/be able to:** • Explain that the collision of molecules can break and form bonds, producing new molecules • Rationalize that the probability of bonds breaking depends on the kinetic energy of the collision and whether or not it is strong enough to break the bonds	
	Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studies and can provide evidence for causality in explanations of phenomena. **Students should know/be able to:** • Define the relationship between the amount of kinetic energy, the number of collisions, and the reaction rate • Define the relationship between temperature and average kinetic energy	
Connected real-world application	Sour milk (yuck!)	
Bloom's taxonomy level(s) addressed:	Remembering	Understanding
	Applying	Analyzing
	Evaluating	Creating
Draft of prompt	There is a lot of truth to the humorous picture shown above. (Picture this: a sippee cup of milk left in Mrs. Birchard's van by one of her children on a hot summer day….YUCK!) Why is it that we store milk in the refrigerator and not at room temperature?	

<table>
<tr><td></td><td>Apply scientific principles and evidence to provide an explanation for the question stated above. Explain your reasoning. In your response, be sure to include:
A consideration of the differences at the particle level at room temperature and in the refrigerator.
An explanation of what happens at the particle level that causes milk to spoil.
Identification of evidence from other personal experiences in and/or out of class that help explain why the milk will spoil faster if the door is not closed.
An explanation of the science principles that are involved.
Optional: Provide a model using words or pictures that justifies your answer.
Be sure to consider the completeness of your response, supporting details, and accurate use of terms.</td></tr>
<tr><td>Is the questions answerable?</td><td>Yes No</td></tr>
<tr><td>What is the expected task the student should complete in answering the question as written?</td><td>Students should explain the relationship between temperature, kinetic energy, number (and force) of collisions, and reaction rate. They should use this relationship to explain why milk spoils at warmer temperatures. They may include a model, but it is not required.</td></tr>
<tr><td>Draft of sample response (Can be done by yourself or a colleague)</td><td>Milk spoiling is a chemical reaction and in a chemical reaction, temperature affects at what rate the reaction occurs. In a cooler environment, the milk is going to last longer because the reactants that form the spoiled milk are interacting less often because they are moving at a slower speed than if it was at room temperature. At a warmer temperature, bacteria particles can form more rapidly. This then causes the milk to spoil. Occasionally I will forget to either drink all of a glass of milk or pour it and then leave it out. The next day when I go to dump it you can see the clumps that have formed.</td></tr>
</table>

Student Copy: Spoiled Milk

Photo Credit: http://www.boredpanda.com/funny-passive-aggressive-office-notes/

(An amusing cartoon of 'spoiled milk' was added when a worker requested their colleagues shut the fridge door to stop it from spoiling)

There is a lot of truth to the humorous picture shown above. (Picture this: a sippee cup of milk left in Mrs. Birchard's van by one of her children on a hot summer day….YUCK!) Why is it that we store milk in the refrigerator and not at room temperature?

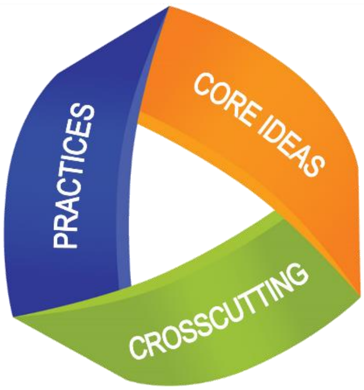
Apply scientific principles and evidence to provide an explanation for the question stated above. Explain your reasoning. In your response, be sure to include:

- A consideration of the differences at the particle level at room temperature and in the refrigerator.
- An explanation of what happens at the particle level that causes milk to spoil.
- Identification of evidence from other personal experiences in and/or out of class that help explain why the milk will spoil faster if left at room temperature.
- An explanation of the science principles that are involved.
- Optional: Provide a model using words or pictures that justifies your answer.

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Teacher Notes: Spoiled Milk

NGSS/Iowa Core Alignment: Performance Expectation: HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.



Science and Engineering Practices: Constructing Explanations and Designing Solutions: Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effect.

Disciplinary Core Ideas: PS1.B: Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

Crosscutting Concepts: Patterns: Different patterns may be observed at each of the scales at which a system is studies and can provide evidence for causality in explanations of phenomena.

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) bond, colliding particles, collision, effect, kinetic energy, molecule, particles, probability, rate, reaction, reaction rate, temperature

Assessment Guide: Spoiled Milk

Criterion:	Exceptional	Skilled	Proficient	Developing
Particle Level	Uses the relationship between temperature (amount of kinetic energy) and the number of collisions to explain why the cooler refrigerator spoils milk slower	Tries to explain what is going on at the particle level, but omits one step in this process: lower temperature = lower kinetic energy = fewer collisions = slower reaction	Has 1-2 errors or omissions in their explanation of what is going on at the particle level	Makes no effort to explain what is going on at the particle level
Personal Experiences	Includes evidence from their personal experiences that correctly align with how concentration affects reaction rate and explains the connection(s)	Brings up personal experiences that are related but does not explain	Brings up personal experiences that are not correctly related	Does not mention any personal connections to the question
Model (optional)	Has a model that correctly justifies their response.	Has a model, but it lacks the detail needed to justify their response.	Has a model, but aspects of it are incorrect.	No model is provided.

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Spoiled Milk**

Assessment Criteria	Evidence of Quality		Comments
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	This writing prompt uses spoiled milk to motivate students to make sense of how temperature affects reaction rates
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	This assessment asks students to explain (make sense) why milk doesn't spoil as fast when it is in the refrigerator
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Students need to construct an explanation using scientific principles to answer the writing prompt question
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students need to explain what is happening at the particle level
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students should identify the relationship that lower temperature = fewer collisions and fewer collisions = slower reaction
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	Students are designing solutions, justifying why one of the responses would work better than the others
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	**Express** (explain what happens at the particle level) **interpret** (identify evidence from other personal experiences) **represent** (optional model)
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	The bulleted items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	Personal Experiences (SEP), Particle Level (DCI and CCC)
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency that help make this accessible to all students. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level.

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

Overall Summary Comments: Like with the Stained Uniform writing prompt, I worry that students will worry about the actual mechanism of the reaction causing milk to spoil which is not the objective of this prompt. They will get to learn about those concepts next year. If I can get them past that bump, I think they should do well with this prompt.

Conservation of Matter: Candle Wax

Developing Quality Writing Prompts: A Teacher Tool

NGSS Performance Expectation this prompt assesses:	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
NGSS dimensions assessed:	*Science and Engineering Practices: Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to support claims* **Students should know/be able to:** • Calculate the mass of any component of a reaction, given any other component • Describe how the mass of a substance can be used to determine the number of atoms, molecules or ions • Count the amount of reactants and products of a chemical reaction in terms of atoms, moles and mass • Calculate the molar mass of all components of the reaction • Use a balanced chemical equation • Use the mole to convert between the atomic and the macroscopic scale
	Disciplinary Core Ideas: PS1.B: Chemical Reactions: The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **Students should know/be able to:** • Predict the relative number of atoms in the reactants versus the products at the atomic scale
	Crosscutting Concepts: Energy and Matter: The total amount of energy and matter in closed systems is conserved. *Scientific Knowledge Assumes and Order and Consistency in Natural Systems: Science assumes the universe is a vast single system in which basic laws are consistent* **Students should know/be able to:** • Make the claim that atoms, and therefore mass, are conserved during a chemical reaction
Connected real-world application	Birthday candles
Bloom's taxonomy level(s) addressed:	Remembering Understanding Applying Analyzing Evaluating Creating

Draft of prompt	Candles come in all sorts of different shapes, colors, and sizes. When they are lit, the fire wick burns down and the wax melts. Somehow there seems to be much less wax left as the candle burns. This would appear to violate the Law of Conservation of Mass, but we have learned that this law cannot be violated. Verify, using mathematical representations, that the mass is truly conserved. You are given the following information to use in your explanation: Most candles are made using paraffin wax, which commonly has the chemical formula $C_{25}H_{52}$. Paraffin burns according to the following, unbalanced chemical equation: $C_{25}H_{52} + O_2 \rightarrow CO_2 + H_2O$ + heat ***<u>An unlit birthday candle's height and mass are recorded. It is then placed into a small lump of clay so that it will remain upright, and its height and mass are recorded as it burns.</u>***

Candle Height (cm)	Mass (g)	Burn Time (min)
8.13	3.3	0
7.49	3.2	2
6.73	3.1	4
6.35	2.9	6
5.97	2.7	8
5.72	2.7	10
5.46	2.6	12
5.08	2.4	14
4.45	2.2	16
4.32	2.0	18
3.36	1.8	20

Use mathematical representations to verify that the Law of Conservation of Mass is upheld in the burning of a birthday candle. Explain your reasoning. In your response, be sure to include:

- Describe the type of chemical reaction that is occurring, as well as identifying any and all reactants and products.
- How could you verify that the products you described are being produced?
- Choose one data set from the experiment described (i.e. 4 minutes). How much paraffin was reacted? How do you know?

	• An explanation of the science principles that are involved. In other words, explain the “loss” of mass of the candle in terms of the Law of Conservation of Mass. • Optional: Provide a model using words or pictures that justifies your answer. Be sure to consider the completeness of your response, supporting details, and accurate use of terms.
Is the questions answerable?	Yes No
What is the expected task the student should complete in answering the question as written?	Students should identify this as a combustion reaction because water and carbon dioxide are the products, and identify the paraffin and oxygen as the reactants and water and carbon dioxide as the products. They should describe a method to verify that carbon dioxide and water are being produced. (We have discussed these methods in class prior.) Students should select one data set and determine how much wax was reacted (by subtracting from how much they started with) and describe what happened to the mass that was missing. They should use the phrase Law of Conservation of Mass in their response.
Draft of sample response (Can be done by yourself or a colleague)	While this reaction may look like it violates the Law of Conservation of Mass, it really doesn’t. When you burn something you cause a chemical reaction called a combustion reaction. This produces carbon dioxide and water and the reactants are paraffin ($C_{25}H_{52}$) and oxygen. To verify the identity of the products, you could try to contain the gas being produced. If it has CO_2 in it the gas collected would put out a flame. You would probably also notice condensation in your collection container because the water vapor that is given off is being cooled and condenses. At the 10 minute mark, 0.6 grams of paraffin wax had reacted. You can tell this because the change in mass from 0 minutes to 10 minutes is 0.6 grams. This mass hasn’t been destroyed, it has just been converted into carbon dioxide and water vapor that have escaped and are not being massed with the candle.

Student Copy: Candle Wax

Photo Credit: https://www.ngssphenomena.com/

Candles come in all sorts of different shapes, colors, and sizes. When they are lit, the fire wick burns down and the wax melts. Somehow there seems to be much less wax left as the candle burns. This would appear to violate the Law of Conservation of Mass, but we have learned that this law cannot be violated. Verify, using mathematical representations, that the mass is truly conserved. You are given the following information to use in your explanation: Most candles are made using paraffin wax, which commonly has the chemical formula $C_{25}H_{52}$. Paraffin burns according to the following, unbalanced chemical equation:

$$C_{25}H_{52} + O_2 \rightarrow CO_2 + H_2O + \text{heat}$$

An unlit birthday candle's height and mass are recorded. It is then placed into a small lump of clay so that it will remain upright, and its height and mass are recorded as it burns.

Candle Height (cm)	Mass (g)	Burn Time (min)
8.13	3.3	0
7.49	3.2	2
6.73	3.1	4
6.35	2.9	6
5.97	2.7	8
5.72	2.7	10
5.46	2.6	12
5.08	2.4	14
4.45	2.2	16
4.32	2.0	18
3.36	1.8	20

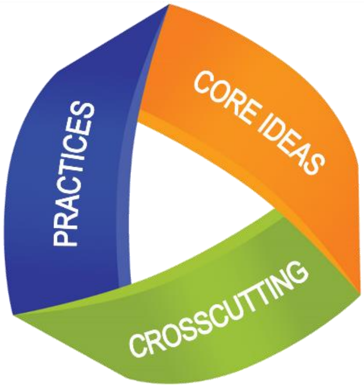
Use mathematical representations to verify that the Law of Conservation of Mass is upheld in the burning of a birthday candle. Explain your reasoning. In your response, be sure to include:

- Describe the type of chemical reaction that is occurring, as well as identifying any and all reactants and products. Make sure to discuss the phases of matter each reactant and product is in.
- How could you verify that the products you described are being produced?
- Choose one data set from the experiment described (i.e. 4 minutes). How much paraffin was reacted? How do you know?
- An explanation of the science principles that are involved. In other words, explain the "loss" of mass of the candle in terms of the Law of Conservation of Mass.
- Optional: Provide a model using words or pictures that justifies your answer.

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Teacher Notes: Candle Wax

NGSS/Iowa Core Alignment: Performance Expectation: HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.



Science and Engineering Practices: Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to support claims.

Disciplinary Core Ideas: PS1.B: Chemical Reactions: The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Crosscutting Concepts: Energy and Matter: The total amount of energy and matter in closed systems is conserved.

Scientific Knowledge Assumes and Order and Consistency in Natural Systems: Science assumes the universe is a vast single system in which basic laws are consistent

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) atomic, atoms, Avogadro’s number, balanced chemical equation, chemical reaction, conserved, Law of Conservation of Matter, macroscopic, mass, molar mass, mole, molecules, stoichiometry

Assessment Guide: Candle Wax

Criterion:	Exceptional	Skilled	Proficient	Developing
Reaction Details	Correctly identifies and justifies this as a combustion reaction, listing paraffin and oxygen as the reactants and carbon dioxide and water as the products	Correctly identifies this as a combustion reaction, but doesn't justify their response. Correctly lists the products and reactants.	Either identifies this as a combustion reaction OR identifies the reactants and products, but does not do both or has some errors in their justification.	Incorrectly identifies the reaction type and reactants/products
Verification	Discusses viable procedures that could be used to verify carbon dioxide and water as products	Correctly describes how to verify one product but not the other	Attempts to describe how to verify products, but has errors	Has no mention of how you could verify the products or answers "Google"
Loss of Paraffin	Selects one (or more) data sets and correctly calculates the amount of paraffin lost	Selects one (or more) data sets and calculates the amount of paraffin lost, but makes 1-2 errors	Selects one (or more) data sets and incorrectly calculates the amount of paraffin lost	Makes no mention of this
Law of Conservation of Mass	Correctly explains how we can "lose" mass of paraffin and still maintain the Law of Conservation of Mass	Tries to explain how the Law of Conservation of Mass applies, but has errors	Says the Law of Conservation of Mass is upheld, but does not explain how it is shown in this problem	Does not discuss the Law of Conservation of Mass

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Candle Wax**

Assessment Criteria	Evidence of Quality		Comments
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	This writing prompt uses a “disappearing” candle to motivate students to make connections to the Law of Conservation of Mass
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	This assessment asks students to explain (make sense) where the wax is going if it can not disappear (the Law of Conservation of Mass)
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Students need to use mathematical representations to figure out how much paraffin wax is reacted
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students need to explain how the atoms are conserved in the combustion of paraffin
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students need to explain how the atoms are conserved in the combustion of paraffin
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	Students are analyzing data and using it to make claims
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	**Clarify** (what parts of the reaction are the reactants and products, and in which state are they?) **interpret** (identify how much paraffin is being reacted) **justify** (explain how the Law of Conservation of Mass is upheld) **represent** (optional model)
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students’ three-dimensional learning?	Yes	No	The bulleted items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	Reaction Details and Loss of Paraffin (SEP), Law of Conservation of Mass (DCI and CCC)
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency that help make this accessible to all students. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level.

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed**—Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

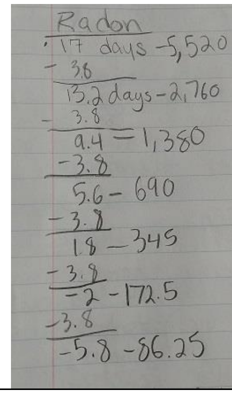
Overall Summary Comments: This prompt does not go into the concept of the mole or stoichiometry type problems, but is a beginning level assessment within the scope of HS-PS1-7. More prompts need to be developed to completely assess this performance expectation.

Nuclear Processes: Radon

Developing Quality Writing Prompts: A Teacher Tool

<table>
<tr><td>NGSS Performance Expectation this prompt assesses:</td><td>HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.</td></tr>
<tr><td rowspan="3">NGSS dimensions assessed:</td><td>Science and Engineering Practices: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system Students should know/be able to:
Develop a model where they
identify an element by the number of protons
represent the change in the number of protons and neutrons in the nucleus before and after the decay
identify the emitted particles
compare the scale of energy change associated with nuclear processes and chemical processes
Develop unique models that illustrate fission, fusion and the three distinct types of radioactive decay</td></tr>
<tr><td>Disciplinary Core Ideas: PS1.C: Nuclear Processes: Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.
Students should know/be able to:
Differentiate between alpha particle emission and beta/gamma emission (DCI)
Describe that energy may be given off in both fission and fusion models, and may require initial energy for the reaction to take place
Illustrate the differences in type of energy and type of particle released during alpha, beta, and gamma radioactive decay, and any change from one element to another than can occur due to the process</td></tr>
<tr><td>Crosscutting Concepts: Energy and Matter: In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
Students should know/be able to:
Connect nuclear processes to the Law of Conservation of Matter</td></tr>
<tr><td>Connected real-world application</td><td>Radon detectors in your house</td></tr>
<tr><td>Bloom's taxonomy level(s) addressed:</td><td>Remembering   Understanding
Applying   Analyzing
Evaluating   Creating</td></tr>
</table>

Draft of prompt	Mollie and her husband, Juan, are in the market for a new house! They have been looking for weeks and finally (finally!) find the house of their dreams. They make an offer on it with their realtor and it is accepted!! Everything is headed in the right direction and they can't wait to move into their new home. Before moving in, they have the house tested for radon (as recommended by the Environmental Protection Agency) and (sad face) it tests high. Really high. Most houses in the United States have some (small) amount of radon in them of approximately 100 Bq/m^3 (let's just call that 100 units). Mollie and Juan's house had 5,520 units! (Unfortunately, the highest average radon concentrations in the United States are found in Iowa due to the same glaciation that makes our farmland so rich!) Mollie and Juan are able to hire a contractor to make some changes to their foundation that would reduce the amount of radon that is coming into their new home to a more normal rate, but still need to figure out how long they have to wait for the radon that is currently in their house to decompose after the contractor finishes his job so they know when they can move in. They know that radon decays with a half-life of 3.8 days. Use your mathematical thinking skills to compose a method to determine how long it will take 5,520 units of radon to decay to less than 100 units and then use that method to calculate the correct answer. If the contractor can finish the job by August 15, can they move in before the end of August? In your answer, please also consider what half-life is and how it can be used to help answer this question. Also keep in mind that the Law of Conservation of Matter always applies, so as the radon is decaying, please explain where it is going/what is happening. Explain how this is different from a chemical reaction. Be sure to consider the completeness of your response, supporting details, and accurate use of terms.
Is the questions answerable?	Yes No
What is the expected task the student should complete in answering the question as written?	Students should calculate the number of days it would take the radon to decay to <100 units. Every 3.8 days the amount would decrease by half. They might make a table. They might show an equation. They should then use that information to figure out what day they could move in and compare it to August 31 to see if they meet the move-in deadline. They should also explain how the Law of Conservation of Matter applies and what is happening at the microscopic level. They should be able to explain where the decayed radon goes.
Draft of sample response (Can be done by yourself or a colleague)	A half life is the amount of time it takes for the amount of radioactive matter to be cut in half. So every 3.8 days, the amount of radon present would be cut in half. Using this you can find how long it takes the radon to decay to only 100 units. They would not be able to move in by the end of August. It would be about 5.8 more days after August. Matter isn't disappearing, it's just in a different form. The radon is decomposing into

<table>
<tr>
<td></td>
<td>a different, lighter element that is not radioactive. In a regular chemical reaction, you have the same number of atoms of the same elements, they just get rearranged. Here you have new elements that weren’t there before, but what is conserved is the number of subatomic particles. The total number protons and neutrons are not changing. This is like the lab we did, where when we had a radioactive atom decay we had to put in the bingo chip that represented the new atom formed.

</td>
</tr>
</table>

Student Copy: Radon

Mollie and her husband, Juan, are in the market for a new house! They have been looking for weeks and finally (finally!) find the house of their dreams. They make an offer on it with their realtor and it is accepted!! Everything is headed in the right direction and they can't wait to move into their new home. Before moving in, they have the house tested for radon (as recommended by the Environmental Protection Agency) and (sad face) it tests high. Really high. Most houses in the United States have some (small) amount of radon in them of approximately 100 Bq/m^3 (let's just call that 100 units). Mollie and Juan's house had 5,520 units! (Unfortunately, the highest average radon concentrations in the United States are found in Iowa due to the same glaciation that makes our farmland so rich!)

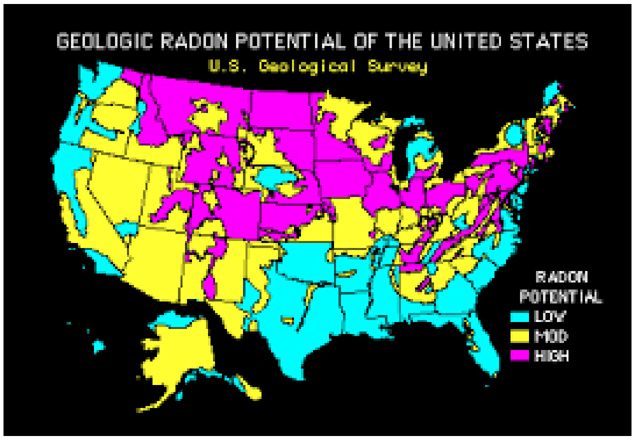


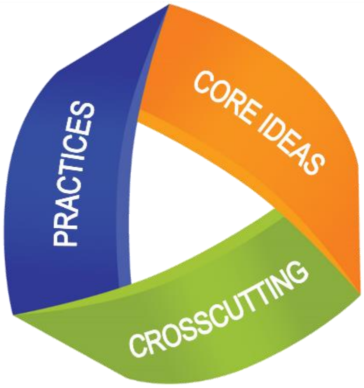
Photo Credit: https://certmapper.cr.usgs.gov/data/PubArchives/radon/usrnpot.gif

Mollie and Juan are able to hire a contractor to make some changes to their foundation that would reduce the amount of radon that is coming into their new home to a more normal rate, but still need to figure out how long they have to wait for the radon that is currently in their house to decompose after the contractor finishes his job so they know when they can move in. They know that radon decays with a half-life of 3.8 days.

> Use your mathematical thinking skills to compose a method to determine how long it will take 5,520 units of radon to decay to less than 100 units and then use that method to calculate the correct answer. If the contractor can finish the job by August 15, can they move in before the end of August? In your answer, please also consider what half-life is and how it can be used to help answer this question. Also keep in mind that the Law of Conservation of Matter always applies, so as the radon is decaying, please explain where it is going/what is happening. Explain how this is different from a chemical reaction.
>
> Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Teacher Notes: Radon

NGSS/Iowa Core Alignment: Performance Expectation: HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.



Science and Engineering Practices: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas: PS1.C: Nuclear Processes: Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

Crosscutting Concepts: Energy and Matter: In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

**Appropriate terms: (Students should be able to use appropriately some, if not all, of the following vocabulary words in their response) absorption, alpha, atom, beta, conserved, electrons, emission, energy, fission, fusion, gamma, half-life, model, neutrons, nuclear, nucleus, positrons, process, protons, radioactive decay, release, scale

Assessment Guide: Radon

Criterion:	Exceptional	Skilled	Proficient	Developing
Move-In Date	Correctly identifies that Mollie and Juan will NOT be able to move in on August 31 and says how much longer it will be	Correctly identifies that Mollie and Juan will NOT be able to move in on August 31 but does not specify how many more days are needed	Correctly identifies how many days it will be until there is less than 100 units of radon remaining, but doesn't make the connection that this means they will be unable to move in on August 31	Incorrectly states that Mollie and Juan can move in on August 31
Half-Life	Accurately describes what half-life is and how it impacts their response about the move in date	Accurately describes what half-life is but doesn't describe its impact on this problem	Describes what half-life is/its impact on their response, but has some errors	Does not mention half-life in their response
Calculations	Describes a correct method for calculating how long it will take the radon to decay to the necessary levels. Work is shown and is correct.	Describes a correct method for calculating how long it will take the radon to decay to the necessary levels, but doesn't show the work	Describes/shows a method for calculating how long it will take the radon to decay to the necessary levels, but has some errors in their calculations (or work)?	Doesn't explain how they found their answer. The answer is incorrect.
Law of Conservation of Matter	Correctly discusses where the matter is going as radon decays to maintain the Law of Conservation of Matter	Discusses the Law of Conservation of Matter but has difficulty explaining where the matter goes as radon decays	Tries to explain where the matter goes, with some errors. May or may not use the phrase "Law of Conservation of Matter"	Thinks that when radon decays that it just disappears
Comparing a Nuclear Reaction to a Chemical Reaction	Correctly discusses the idea that atoms are conserved in a chemical reaction, but subatomic particles are conserved in a nuclear reaction	Compares the two types of reactions with some errors	Makes an attempt to compare the two types of reactions, but doesn't really know what the difference is	Cannot compare the two/makes no effort to compare the two types of reactions

Assessing the Quality of NGSS Aligned Writing Prompt Assessments: A Checklist

(Modified from the EQuIP Rubric for Lessons and Units: Science)

Assessment Title: **Radon**

Assessment Criteria	Evidence of Quality		Comments
• Do student questions or prior experiences related to the performance expectation motivate sense-making and/or problem solving?	Yes	No	To me, radon in the home made this related to prior experiences, but my students didn't know what radon was.
• Is the focus of the assessment to observe how students make sense of phenomena and/or design solutions to problems	Yes	No	Students need to make sense of how half-life influences when Juan and Mollie can move in to their new house
• Does the assessment provide opportunities for students to use specific elements of the SEP(s)?	Yes	No	Students develop a model that allows them to determine how many days it will take to decay the Radon in the house and then figure out if they can move in on time
• Does the assessment provide opportunities for students to use specific elements of the DCI(s)?	Yes	No	Students need to make sense of radioactive decay and what is occurring at the particle level
• Does the assessment provide opportunities for students to use specific elements of the CCC(s)?	Yes	No	Students must explain that while atoms are not conserved the number of particles are
• Is the student engaged in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world?	Yes	No	Students are making calculations based on a model
• Does the assessment provide opportunities for students to express, clarify, justify, interpret, and represent their ideas?	Yes	No	**Express** what half-life is, **interpret** data to determine if Mollie and Juan can move in on time **represent** how half-life will affect the radon in a mathematical model
• Does the assessment use scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning?	Yes	No	The listed items that students are asked to complete match what the NRC document *A Framework for K-12 Science Education* identifies as scientifically accurate and grade-appropriate for this performance expectation
• Does the assessment include aligned rubrics or scoring guidelines that provide guidance for interpreting student performance along the three dimensions?	Yes	No	Calculations (SEP),, Half-Life and Comparing a Nuclear Reaction to a Chemical Reaction (DCI), Law of Conservation of Matter (CCC)
• Does the assessment assess student proficiency using method, vocabulary, representations, and examples that are accessible and unbiased for all students?	Yes	No	The rubric includes varied levels of proficiency that help make this accessible to all students. The vocabulary words used are taken directly from the NGSS performance expectations for HS so they are on grade-level

Overall ratings:	**E: Example of high quality NGSS design**—High quality design for the NGSS; an assessment with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across all criteria of the rubric. (total score ~9-10) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more places; most criteria have at least adequate evidence (total score ~7-8) **R: Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more criteria (total ~4–6) N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–3)	**Circle the overall rating below:** **E E/I R N**

Overall Summary Comments: When asking my students to look at this and give some feedback, they did not know what radon is! (So I marked the first criterion as a no).

Chapter 4

Reflection

The development of this project has provided me a lot of support in my implementation of the Next Generation Science Standards. With Iowa adopting these standards and expecting full implementation by 2020, teachers across the state are faced with the challenge of figuring out the implications of implementation. Our instruction and assessment strategies will have to change, in a positive direction. Before beginning this project, I was part of a group that vetted one of the initial readings of the NGSS, and I have participated in Science Networking projects through Great Prairie AEA to develop curriculum aligned with the NGSS, but I wasn't fully invested. I didn't realize the overwhelming impact these standards were going to have on my teaching. This project has brought me face-to-face with these challenges, and I have pushed my way through to where I feel much more comfortable and a lot more confident in my abilities to teach and assess in a NGSS-aligned classroom.

In the development of these eight writing prompts I have focused on the assessment portion of my classroom, but I have also had to ask myself what the activities and learning will have to look like to prepare my students for these assessments. I think it is important to develop assessments before you develop the lessons so you know where you're headed and can take the right path. While I haven't necessarily sat down and written out these plans for all these assessments yet, I have worked through a few of them already in my classroom, specifically "Radon" and "Popcorn Salt". Examples of student work on these assessments are included in Appendices H and I. While working on the teacher's notes for each of these writing prompts, reflecting on how my students responded, and now considering the evidence statements for each of the performance expectations they align with, I have tweaked both prompts to better align with the expectations of the NGSS, and I expect I will continue to do that with the others as I use them in my classroom. If you compare the questions on the student examples in the Appendices with the student copies in Chapter 3 you will notice a few of these changes. This project is a work in progress, and will continued to be worked on, even after the paper has been turned in because that's the kind of teacher that I am. I am reflective, always wanting to do more than just maintain the status quo. When faced with new challenges, I reach out to find ways to adapt and better prepare my students for their future.

Not only do I expect that I will tweak these eight completed prompts, my long-term goal is to continue developing writing prompts to assess the remaining twelve High School Physical Science Performance Expectations that were identified as aligning with this style of prompts in addition to the six I have already addressed. Within each Performance Expectation more than one prompt can be developed as I did with HS-PS1-4, HS-PS1-5. My 9th Grade Physical Science class is also tasked with some of the Earth Science Performance Expectations as well, so I will eventually take those on as well.

When proposing my project, I was asked a question about how I planned to use these in my classroom. Until that point, my plan was pretty straight-forward. I planned to use them in an individual basis, in a quiet classroom environment, either as a formative or sometimes summative type of assessment. This question though has made me consider other options. If two of the aims of education are to provide students with the resources to be able to communicate their understanding and prepare students for their future endeavors, these assessments should not all be individualized. In their future careers, my students will often be tasked with working in a group to solve problems and with communicating what they find. I am asked to do this all of the time (in addition to seeking out opportunities to do this on my own).

Why not let students work collaboratively, either on a strictly written product, or perhaps introduce it as a whiteboarding project where students have to communicate their response on a whiteboard in writing but then orally communicate their response in front of their peers? This is especially true for performance expectations where I might have more than one writing prompt developed. Hearing and seeing how what other students responded to the same questions, or closely related questions, can have an additional impressive impact on student understanding.

Going forward I have several plans for my continued professional growth. I am excited to complete my Master's degree, but know that I will continue in my education going forward. I don't have plans to seek additional degrees at this time, but continued professional growth is always a goal for me. This project focused solely on my 9^{th} Grade Physical Science curriculum, but I would also be interested in developing similar assessments for my elective classes including Chemistry, Physics, and Advanced Chemistry and figuring out how to apply these performance expectations in those curricula as well. As mentioned in Chapter 1, my initial interest in this project came from work I was doing with my peers in the Great Prairie Area Education Agency through their Science Networking program. I have drifted from this group over the last few years because of a busy schedule, but would be interested in re-joining this collaboration and sharing what I have learned and developed with my peers. It would be enjoyable to work collaboratively to develop additional prompts.

As I become more confident in my abilities to develop assessments and have developed unit designs that precede them, I would be interested in applying to present at the Iowa Science Teaching Section of the Iowa Academy of Science conference that take place each year, or the UNI Science Education Update Conference in the future to share the work I have completed with others teachers that are also working hard to implement the Next Generation Science Standards.

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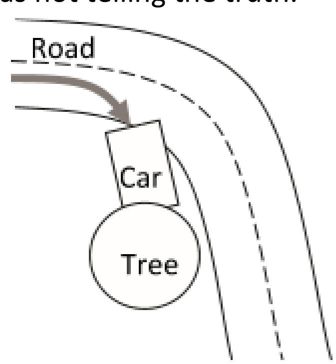
Appendices

Appendix A: Montgomery County Schools Writing Prompt: Car Accident

Unit 1B: Football	Car Accident
Essential Question	In what ways can an object's motion be changed?
Indicator(s)	5.1.1 The student will use analytical techniques appropriate to the study of physics. 5.1.3 The student will analyze and explain how Newton's Laws describe changes in an object's motion.

A police officer is called to the scene of a car accident. In his accident report he sketches the scene and describes it. According to his description the car went off of the road and hit a tree right after a bend. The driver claimed that a second car ran them off the road by hitting them from behind. Using his observations and his knowledge of physics, the police officer determined that the driver was not telling the truth.



Explain how the police officer determined that the car was not run off the road by a second car that came from behind. In your response, be sure to include:

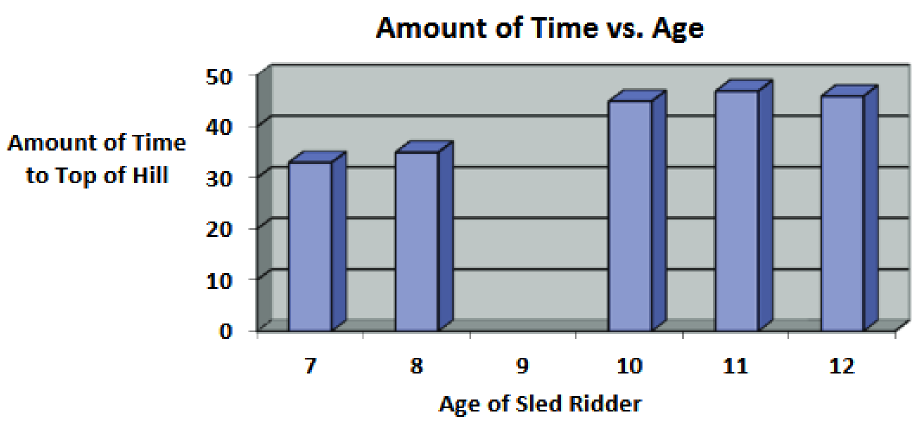
- labels of the forces that would have acted on the car if it were hit from behind.
- labels of the forces that must have acted on the car to have in follow the path indicated with the arrow on the sketch of the scene. how forces affected the motion of the car.

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Appendix B: Montgomery County Schools Writing Prompt: Sledding

Unit **1B: Football**	**Sledding**
Essential Question	How does Newton's second law affect the motion of an object?
Indicator(s)	5.1.2 The student will use algebraic and geometric concepts to qualitatively and quantitatively describe an object's motion. 5.1.3 The student will analyze and explain how Newton's Laws describe changes in an object's motion.

A student comes up with an idea to make some extra money during a snow day. All the neighborhood kids are outside sledding. The student offers to pull the students to the top of the hill for one dollar per ride. The student notices that it was taking more time to pull some student to the top then it was other students even though he was pulling with the same force. He decides to start timing how long it takes to pull each kid and see if there was a pattern based on their age.



Explain why some kids too longer to pull to the top of the hill then other kids despite pulling with the same force. In your response, be sure to include:

- the pattern of the data including any exceptions to the trend.
- the role of Newton's second law in it taking longer to pull some kids.
- a prediction of how long it would take to pull the ten and twelve year olds if they were on the same sled.

Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Appendix C: Constructed Response Organizer

Constructed Response Organizer

Prompt/Question:	
I Restatement of question in own words	
Simple Answer	
Detailed body of evidence that supports answer be sure to include enough details to answer the question Make sure that all details address the question and are not off-topic.	
Restated question Concluding thoughts (if needed)	

Appendix D: A Suggested Process for Writing Constructed Response Questions

A suggested process for writing constructed response questions:

1. Begin with the standard you want to assess. Do you want to find out if your students can predict? Make inferences? Your question needs to match the standard.

2. Determine the level of thinking your students need to attain. We use good 'ole Bloom's Taxonomy of Thinking and encourage teachers to write questions at higher levels of thinking.

3. Draft your question. Make sure that it can be answered in the text. That sounds a bit silly, but you'd be surprised how often we ask questions that just aren't answerable.

4. Practice writing a response - or better yet, ask a colleague to read the passage and answer the question. It really helps to make sure that you've drafted a quality question.

This resource was found on-line at the WritingFix website (http://writingfix.com) Visit WritingFix's Reading in the Content Areas (RICA) section to find even more free teaching resources!

Appendix E: EquIP Rubric for Lessons and Units

Reviewer Name or ID: ________________________________ **Grade:**__________ **Lesson/Unit Title:**____

Category I: NGSS 3D Design (lessons and units): *The lesson/unit is designed so students make sense of phenomena and/or design solutions to problems by engaging in student performances that integrate the three dimensions of the NGSS.*

Lesson and Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials** (what happened/where did it happen) **and reviewer's reasoning** (how/why is this evidence)		**Evidence of Quality?**	**Suggestions for improvement**
A. Explaining Phenomena/Designing Solutions: Making sense of phenomena and/or designing solutions to a problem drive student learning. i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving. ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems. iii. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences.			☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
B. Three Dimensions: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.	Document evidence and reasoning, and evaluate whether or not there is sufficient evidence of quality for each dimension separately	**Evidence of Quality?**	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive **(All 3 dimensions must be rated at least "adequate" to mark "adequate" overall)**	
i. Provides opportunities to develop and use specific elements of the SEP(s).	i.	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive		
ii. Provides opportunities to develop and use specific elements of the DCI(s).	ii .	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive		

iii. Provides opportunities to develop and use specific elements of the CCC(s). **Evidence needs to be at the element level of the dimensions (see rubric introduction for a description of what is meant by "element")**	iii.	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive
C. Integrating the Three Dimensions: Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive
Rating for Category I. NGSS 3D Design—lessons After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which there is enough evidence to support a claim that the lesson meets these criteria. **If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria D-F and rate Category I overall below.**	**Lesson Rating scale for Category I (Criteria A–C only)**: **3**: Extensive evidence to meet at least two criteria (and at least adequate evidence for the third) **2**: Adequate evidence to meet all three criteria in the category **1**: Adequate evidence to meet at least one criterion in the category, but insufficient evidence for at least one other criterion **0**: Inadequate (or no) evidence to meet any of the criteria in the category	**Circle Rating** **0 1 2 3** After rating the lesson, read below for next steps

__What's next if the lesson rating is less than a 2?__

*If the rubric is being used to approve or vet resources and the lesson or unit does not score at least a "2" in **Category I: NGSS 3D Designed**, the review should stop and feedback should be provided to the lesson developer(s) to guide revisions. If the rubric is being used locally for revising and building lessons, professional judgment should guide whether to continue reviewing the lesson. Categories II and III may be time consuming to evaluate if*

Category I has not been met and the feedback may not be useful if significant revisions are needed in Category I, but evaluating these criteria in a group may support deeper and more common understanding of the criteria in these categories and more complete feedback to the lesson developer (if they are not in the room) so that Categories II and III are more likely to be met with fewer cycles of revision.

<u>What's next if the lesson rating is a 2 or 3?</u>

If you are evaluating a lesson that shows sufficient evidence of quality to warrant a rating of either a 2 or a 3 for Category I, proceed to Category II: NGSS Instructional Supports

Category II: NGSS Instructional Supports (lessons and units): *The lesson/unit supports three-dimensional teaching and learning for ALL students by placing the lesson in a sequence of learning for all three dimensions and providing support for teachers to engage all students.*

Lesson and Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials and reviewers' reasoning**	**Evidence of Quality?**	**Suggestions for improvement**
A. Relevance and Authenticity: Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world. i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations). ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate. iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	

B. **Student Ideas:** Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and respond to peer and teacher feedback orally and/or in written form as appropriate.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive
C. **Building Progressions**: Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers: i. Explicitly identifying prior student learning expected for all three dimensions ii. Clearly explaining how the prior learning will be built upon.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive
D. **Scientific Accuracy**: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive
E. **Differentiated Instruction**: Provides guidance for teachers to support differentiated instruction by including: i. Appropriate reading, writing, listening, and/or speaking alternatives (e.g., translations, picture		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive

support, graphic organizers, etc.) for students who are English language learners, have special needs, or read well below the grade level. ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations. iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.		
Rating for Category II: Instructional Supports—lessons After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the lesson met this category. **If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria F–G and rate Category II overall below.**	**Lesson Rating scale for Category II (Criteria A-E only):** **3**: At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion **2**: Some evidence for all criteria in the category and adequate evidence for at least four criteria, including A **1**: Adequate evidence of quality for at least two criteria in the category **0**: Adequate evidence of quality for no more than one criterion in the category	**Circle Rating** **0 1 2 3**

Category III: Monitoring NGSS Student Progress (lessons and units) *The lesson/unit supports monitoring student progress in all three dimensions of the NGSS as students make sense of phenomena and/or design solutions to problems.*

Lesson and Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials and reviewers' reasoning**	**Evidence of Quality?**	**Suggestions for improvement**
A. Monitoring 3D student performances: Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
B. Formative: Embeds formative assessment processes throughout that evaluate student learning to inform instruction.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
C. Scoring guidance: Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
D. Unbiased tasks/items: Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
Rating for Category III. Monitoring NGSS Student Progress—lessons After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the lesson met this category.	**Lesson Rating scale for Category III (Criteria A–D only):** **3**: At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion **2**: Some evidence for all criteria in the category and adequate evidence for at least		**Circle Rating** **0 1 2 3**

If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria E–F and rate Category III overall below.	three criteria, including A **1**: Adequate evidence for at least two criteria in the category **0**: Adequate evidence for no more than one criterion in the category

Category Ratings:

Transfer your team's ratings from each category to the following chart and add the scores together for the overall score:

Category ratings			
Category I: NGSS 3D Design	**Category II: NGSS Instructional Supports**	**Category III: Monitoring NGSS Student Progress**	**Total Score**
0 1 2 3	0 1 2 3	0 1 2 3	

Overall ratings:

The score total is an approximate guide for the rating. Reviewers should use the evidence of quality across categories to guide the final rating. In other words, the rating could differ from the total score recommendations if the reviewer has evidence to support this variation.

E: Example of high quality NGSS design—High quality design for the NGSS across all three categories of the rubric; a lesson or unit with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across Categories I, II, & III of the rubric. (total score ~8–9)

E/I: Example of high quality NGSS design if Improved—Adequate design for the NGSS, but would benefit from some improvement in one or more categories; most criteria have at least adequate evidence (total score ~6–7)

R: Revision needed—Partially designed for the NGSS, but needs significant revision in one or more categories (total ~3–5)

N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–2)

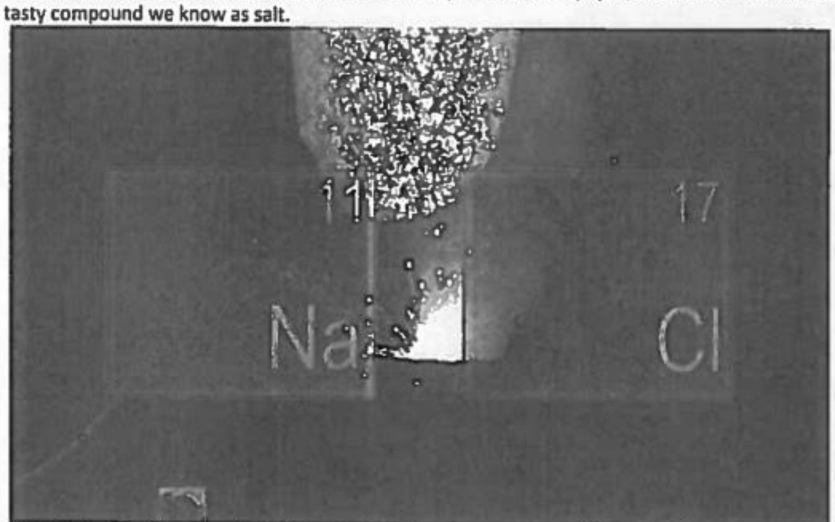
Circle the overall rating below:

E E/I R N

Overall Summary Comments:

Appendix F: Student Sample: "Popcorn Salt"

20. Chlorine, a halogen, is found in group 17 on the periodic table. It is known to be extremely violent, and was even used as a deadly poison during World War I. Sodium, an alkali metal, is found in group 1 on the periodic table. It is also known to be extremely violent, exploding when combined with water. Yet, when combined as shown in the picture below, they fill the net of popcorn above the reaction with a tasty compound we know as salt.



Two students, Alfred and Theresa watch this reaction take place and have the following conversation:
Alfred – No way would I eat that popcorn. Sodium and chlorine?! They're both deadly! I love popcorn, but heck no! I don't want to die.
Theresa – I'd try it. They said it made salt, right? I like salt!

1. I agree more with Theresa because its salt So why couldn't you eat it.
2. Chemical reaction because your making a new solid and there's a temp change.
3. The particles are hitting each other really fast because there is heat and heat make particles go faster.
4. They act the way they do because there valence electrons add up to eight.
5. They act that way because when you get the elements whos valence electrons add up to eight they are happy and that is why they act like that. And one has to get rid of electrons to get to eight and one has to add electrons to get to eight.

Na. + :Cl: = 8 valence electrons
So they are happy

Appendix G: Student Sample: "Radon"

20. Mollie and her husband, Juan, are in the market for a new house! They have been looking for weeks and finally (finally!) find the house of their dreams. They make an offer on it with their realtor and it is accepted!! Everything is headed in the right direction and they can't wait to move into their new home. Before moving in, they have the house tested for radon (as recommended by the Environmental Protection Agency) and (sad face) it tests high. Really high. Most houses in the United States have some (small) amount of radon in them of approximately 100 Bq/m^3 (let's just call that 100 units). Mollie and Juan's house had 5,520 units! (Unfortunately, the highest average radon concentrations in the United States are found in Iowa due to the same glaciation that makes our farmland so rich!)

Mollie and Juan are able to hire a contractor to make some changes to their foundation that would reduce the amount of radon that is coming into their new home to a more normal rate, but still need to figure out how long they have to wait for the radon that is currently in their house to decompose after the contractor finishes his job so they know when they can move in. They know that radon decays with a half-life of 3.8 days.

> Use your mathematical thinking skills to compose a method to determine how long it will take 5,520 units of radon to decay to less than 100 units and then use that method to calculate the correct answer. If the contractor can finish the job by August 15, can they move in before the end of August? In your answer, please also consider what half-life is and how it can be used to help answer this question.
> Be sure to consider the completeness of your response, supporting details, and accurate use of terms.

Days	radiation
3.8	5,520
16.6	2760
14.4	1380
18.2	690
22	345
25.8	172.5
29.6	86.25

← half life

2760
2) 5520
4
15
~~14~~
12

I will take 29.6 day to decay to less than 100 units so they cannot move in before the end of August.

Appendix H: Common Core State Standards Writing Rubric (Grades 9-10): Argument

ARGUMENT					
Description	**5 Exceptional**	**4 Skilled**	**3 Proficient**	**2 Developing**	**1 Inadequate**
Claim: The text introduces a clear, arguable claim that can be supported by reasons and evidence.	The text introduces a compelling claim that is clearly arguable and takes a purposeful position on an issue. The text has a structure and organization that is carefully crafted to support the claim.	The text introduces a precise claim that is clearly arguable and takes an identifiable position on an issue. The text has an effective structure and organization that is aligned with the claim.	The text introduces a claim that is arguable and takes a position. The text has a structure and organization that is aligned with the claim.	The text contains an unclear or emerging claim that suggests a vague position. The text attempts a structure and organization to support the position.	The text contains an unidentifiable claim or vague position. The text has limited structure and organization.
Development: The text provides sufficient data and evidence to back up the claim as well as a conclusion that supports the argument.	The text provides convincing and relevant data and evidence to back up the claim and effectively addresses counterclaims. The conclusion strengthens the claim and evidence.	The text provides sufficient and relevant data and evidence to back up the claim and addresses counterclaims fairly. The conclusion effectively reinforces the claim and evidence.	The text provides sufficient data and evidence to back up the claim and addresses counterclaims. The conclusion ties to the claim and evidence.	The text provides data and evidence that attempts to back up the claim and unclearly addresses counterclaims or lacks counterclaims. The conclusion merely restates the position.	The text contains limited data and evidence related to the claim and counterclaims or lacks counterclaims. The text may fail to conclude the argument or position.
Audience: The text anticipates the audience's knowledge level and concerns about the claim. The text addresses the specific audience's needs.	The text consistently addresses the audience's knowledge level and concerns about the claim. The text addresses the specific needs of the audience.	The text anticipates the audience's knowledge level and concerns about the claim. The text addresses the specific needs of the audience.	The text considers the audience's knowledge level and concerns about the claim. The text addresses the needs of the audience.	The text illustrates an inconsistent awareness of the audience's knowledge level and needs.	The text lacks an awareness of the audience's knowledge level and needs.
Cohesion: The text uses words, phrases, and clauses to link the major sections of the text, creates cohesion, and clarifies the relationships between the claim and reasons, between reasons and evidence, and between claims and counterclaims.	The text strategically uses words, phrases, and clauses to link the major sections of the text. The text explains the relationships between the claim and reasons as well as the evidence. The text strategically links the counterclaims to the claim.	The text skillfully uses words, phrases, and clauses to link the major sections of the text. The text identifies the relationship between the claim and reasons as well as the evidence. The text effectively links the counterclaims to the claim.	The text uses words, phrases, and clauses to link the major sections of the text. The text connects the claim and reasons. The text links the counterclaims to the claim.	The text contains limited words, phrases, and clauses to link the major sections of the text. The text attempts to connect the claim and reasons.	The text contains few, if any, words, phrases and clauses to link the major sections of the text. The text does not connect the claims and reasons.
Style and Conventions: The text presents a formal, objective tone that demonstrates standard English conventions of usage and mechanics along with discipline-specific requirements (i.e. MLA, APA, etc.).	The text presents an engaging, formal and objective tone. The text intentionally uses standard English conventions of usage and mechanics along with discipline-specific requirements (i.e. MLA, APA, etc.).	The text presents an appropriate and formal, objective tone. The text demonstrates standard English conventions of usage and mechanics along with discipline specific requirements (i.e. MLA, APA, etc.).	The text presents a formal, objective tone. The text demonstrates standard English conventions of usage and mechanics along with discipline specific requirements (i.e. MLA, APA, etc.).	The text illustrates a limited awareness of formal tone. The text demonstrates some accuracy in standard English conventions of usage and mechanics.	The text illustrates a limited awareness or inconsistent tone. The text illustrates inaccuracy in standard English conventions of usage and mechanics.

Appendix I: Rubric for Science Writing (Montgomery County Public Schools)

Advanced (12)	(10)	(9)	Basic (8)
Addresses the prompt completely	Addresses the prompt completely	Addresses the prompt	somewhat addresses the prompt
Consistently uses accurate science vocabulary to appropriately support ideas	Uses accurate science vocabulary to appropriately support ideas	Uses some science vocabulary to support ideas; at times may be inaccurate	Missing science vocabulary and/or inaccurate usage of the vocabulary
clearly develops ideas with complete support/data	clearly develops idea with support/data	develops ideas with some support/data	supports idea
uses logical reasoning to connect the idea to the supports	uses logical reasoning to connect ideas to the supports	uses some reasoning for ideas	uses unclear reasoning for the supports
organizes the writing logically and purposefully	organizes the writing logically and purposefully	shows an organization plan in the writing	attempts to organize writing
contains minimal errors in conventions that do not interfere with readers' understanding	contains minimal errors in conventions that may interfere with readers' understanding	contains errors in conventions that may interfere with some readers' understandings	contains errors that interfere with the readers' understanding